Active Inner Veto for Improved Dark Matter Search and Neutrino Detection Sensitivity

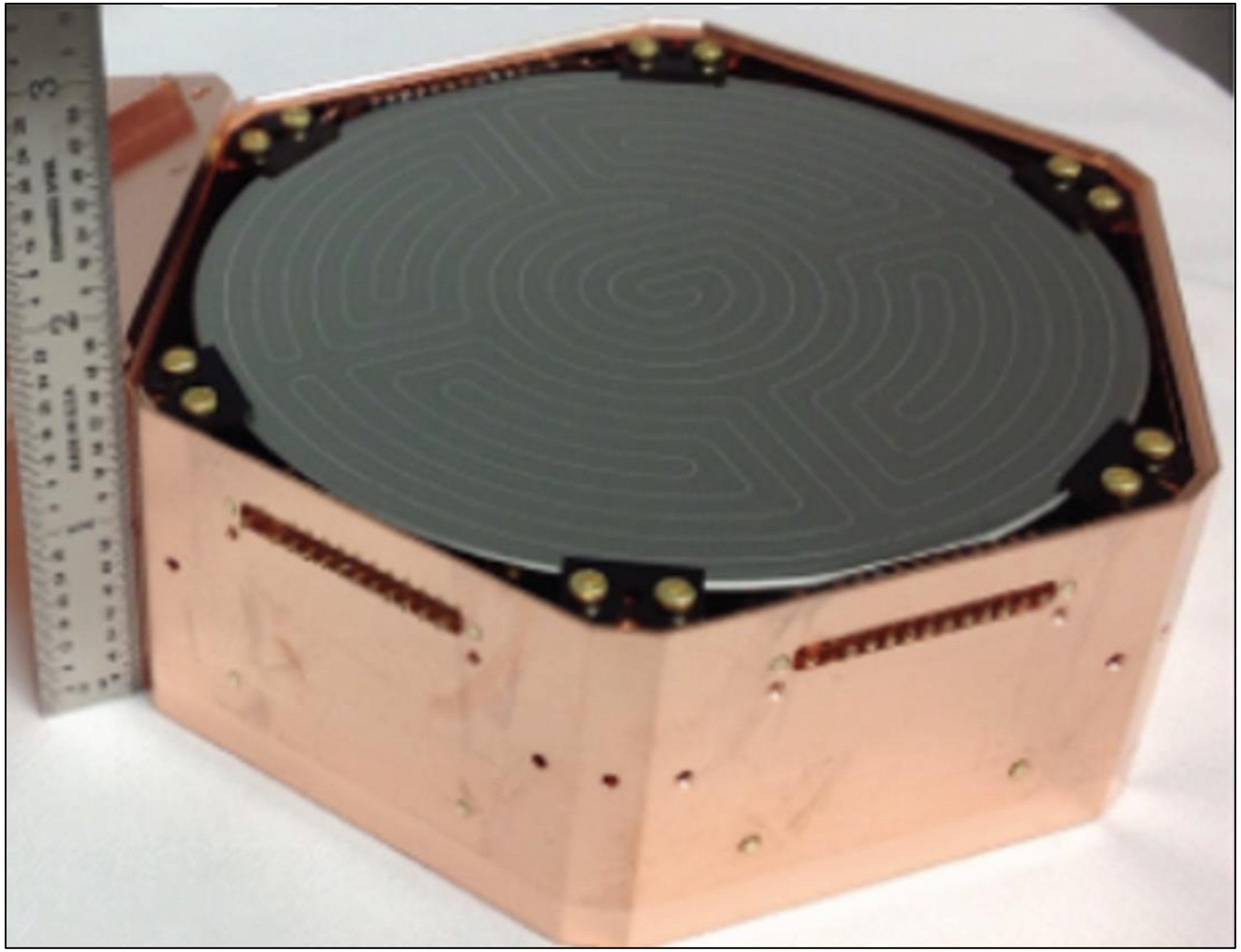
Andrew Jastram

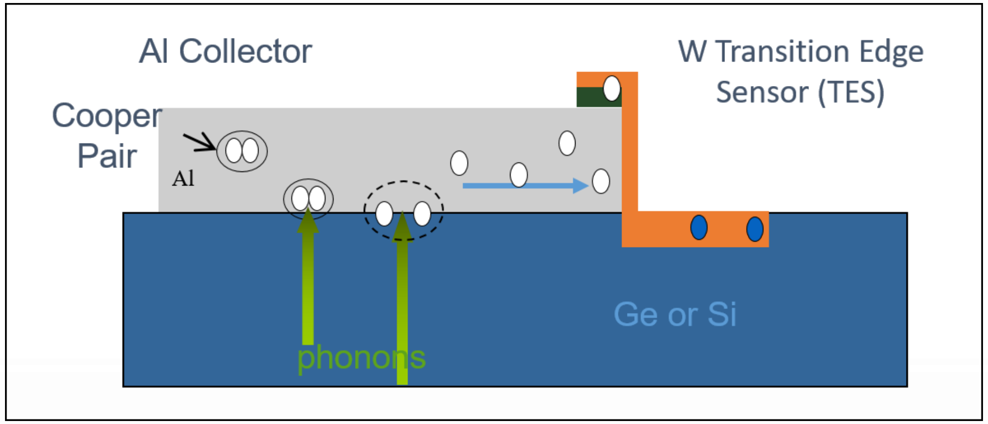
CPAD March 18, 2021

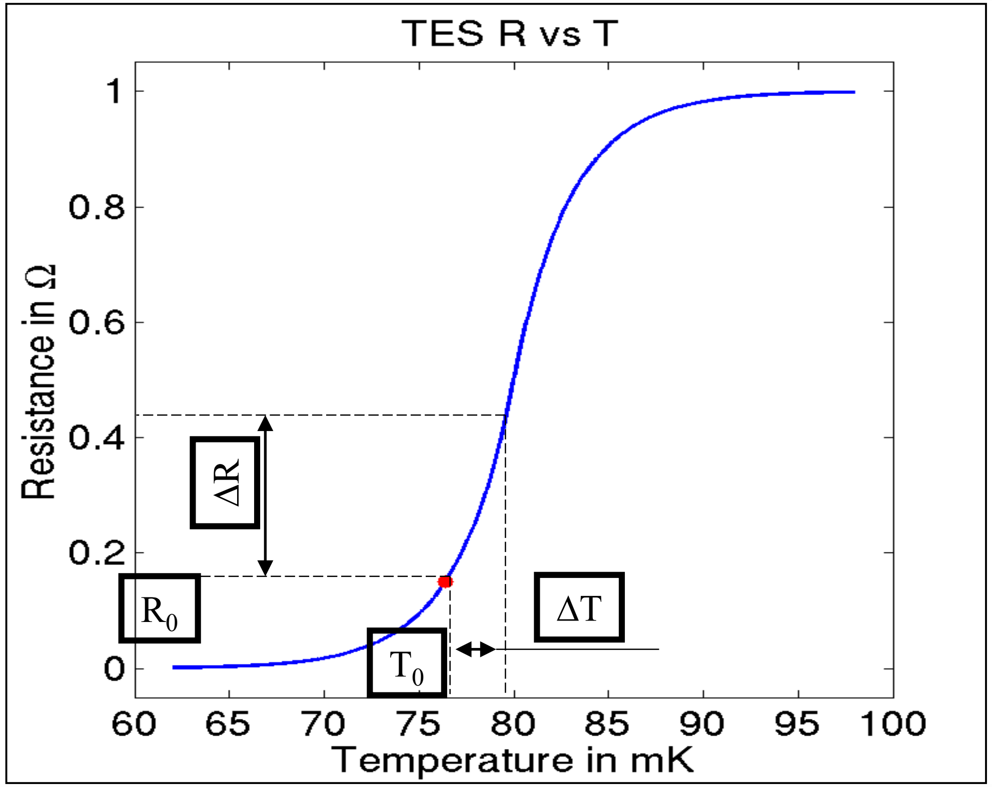
TEXAS A&M UNIVERSITY
Physics & Astronomy

SCDMS/TES Technology

- Transition edge sensors (TES) used to read athermal phonon signals
- Looking for nuclear recoils due to WIMP interactions



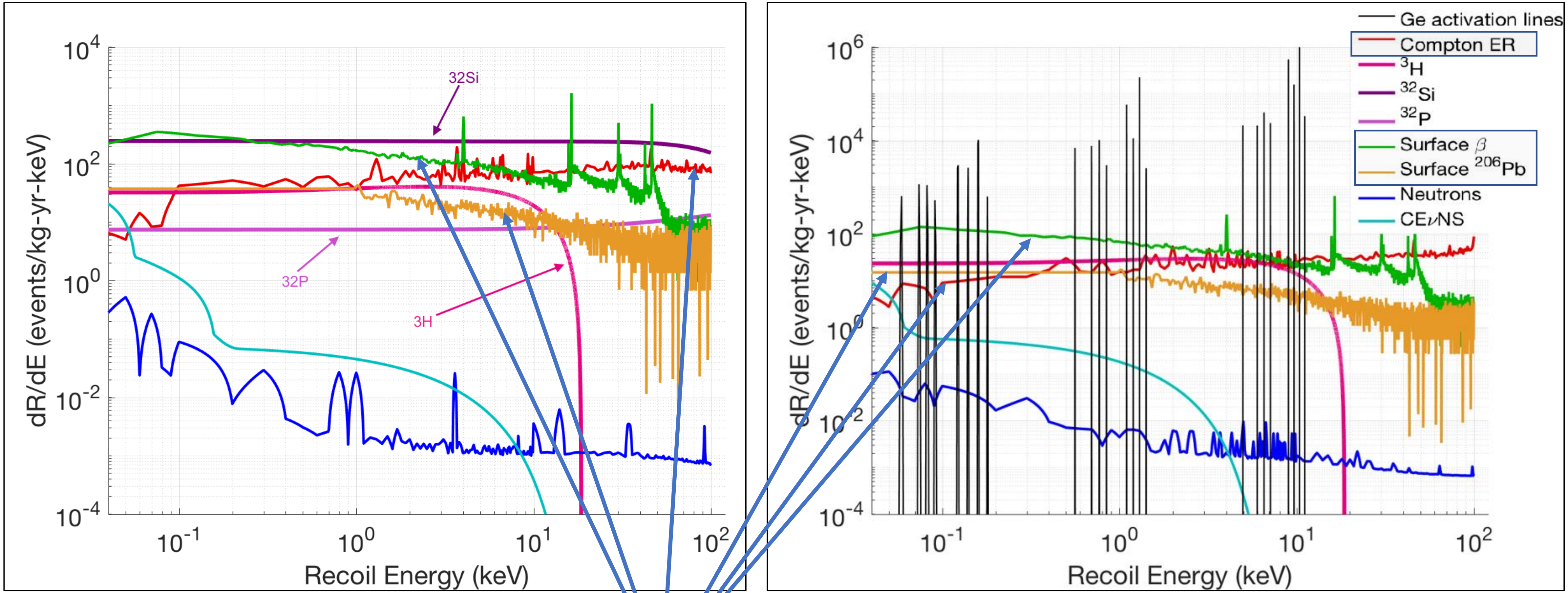




Concept

- Active inner annular Ge veto detector completely (2*pi) surrounding the target detector
  - Neighboring detectors (above and below) complete the 4*pi coverage
- Decay products from housing contamination are entirely blocked from target detector (passive and active shielding)
- Some ambient radiation also shielded (passive and active shielding)
- Gammas that Compton scatter on the way in or out (appearing in both detectors) are tagged in coincidence
- Events from ^{210}Pb on the target detector are tagged due to their ejected decay products triggering the veto as opposed to “escaping” unnoticed
- Use same cold hardware (housing AND readout)…. “plug and play”

Backgrounds of Concern for SCDMS

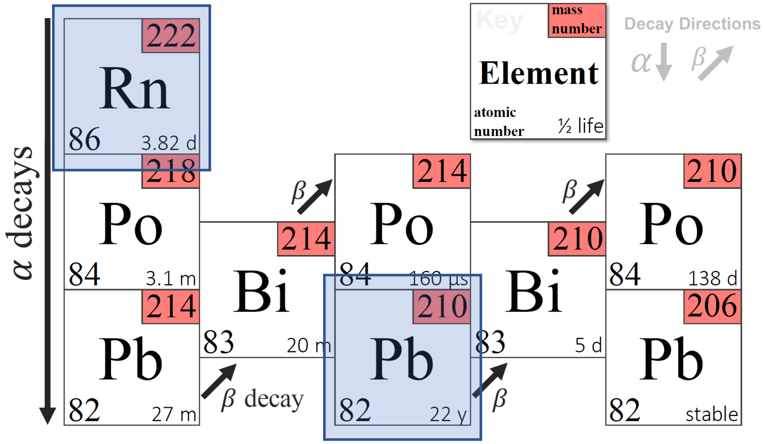


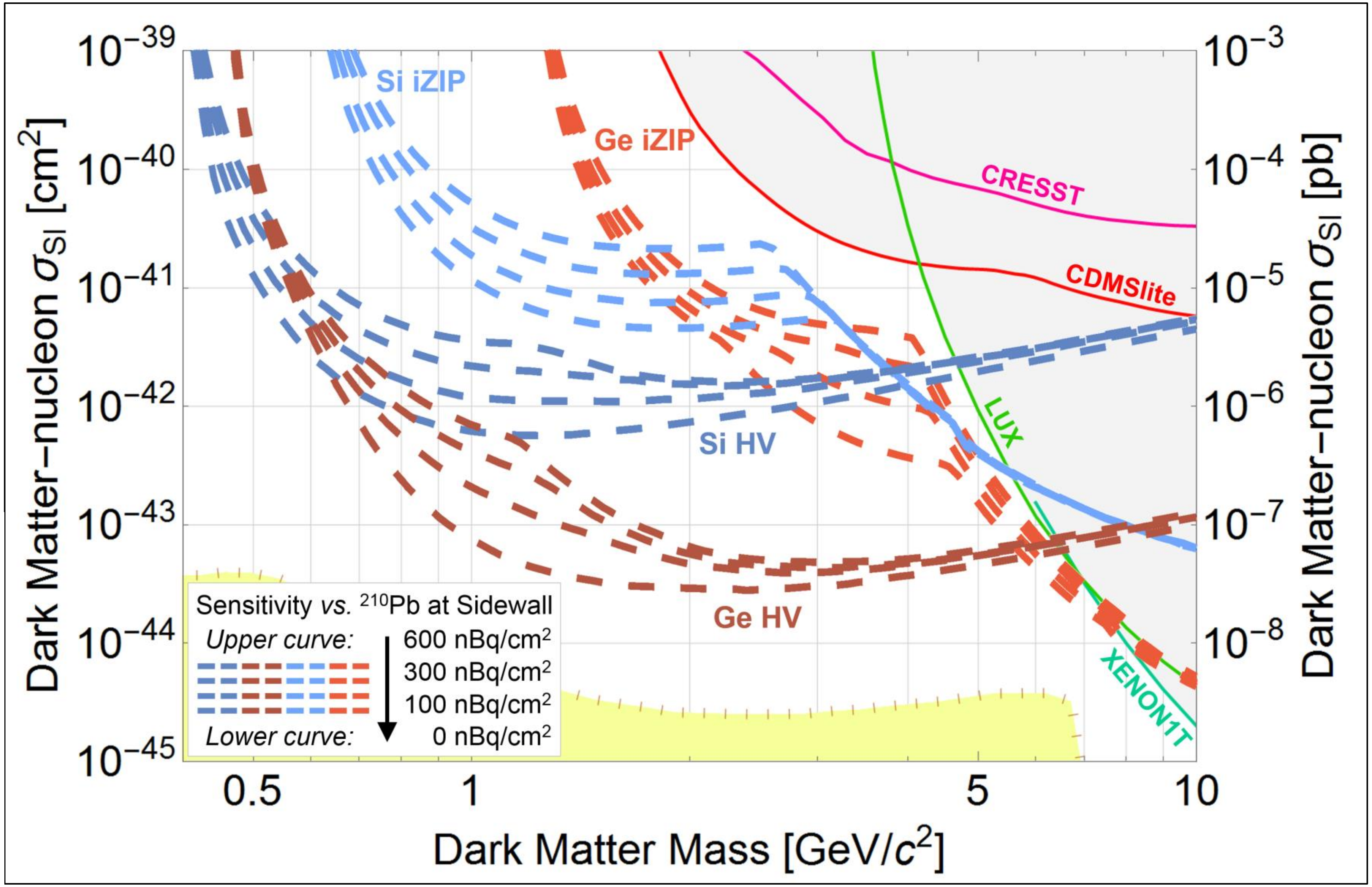
Proposed Detector nearly eliminates these three:

- Compton ER
- Surface β
- Surface ^{206}Pb

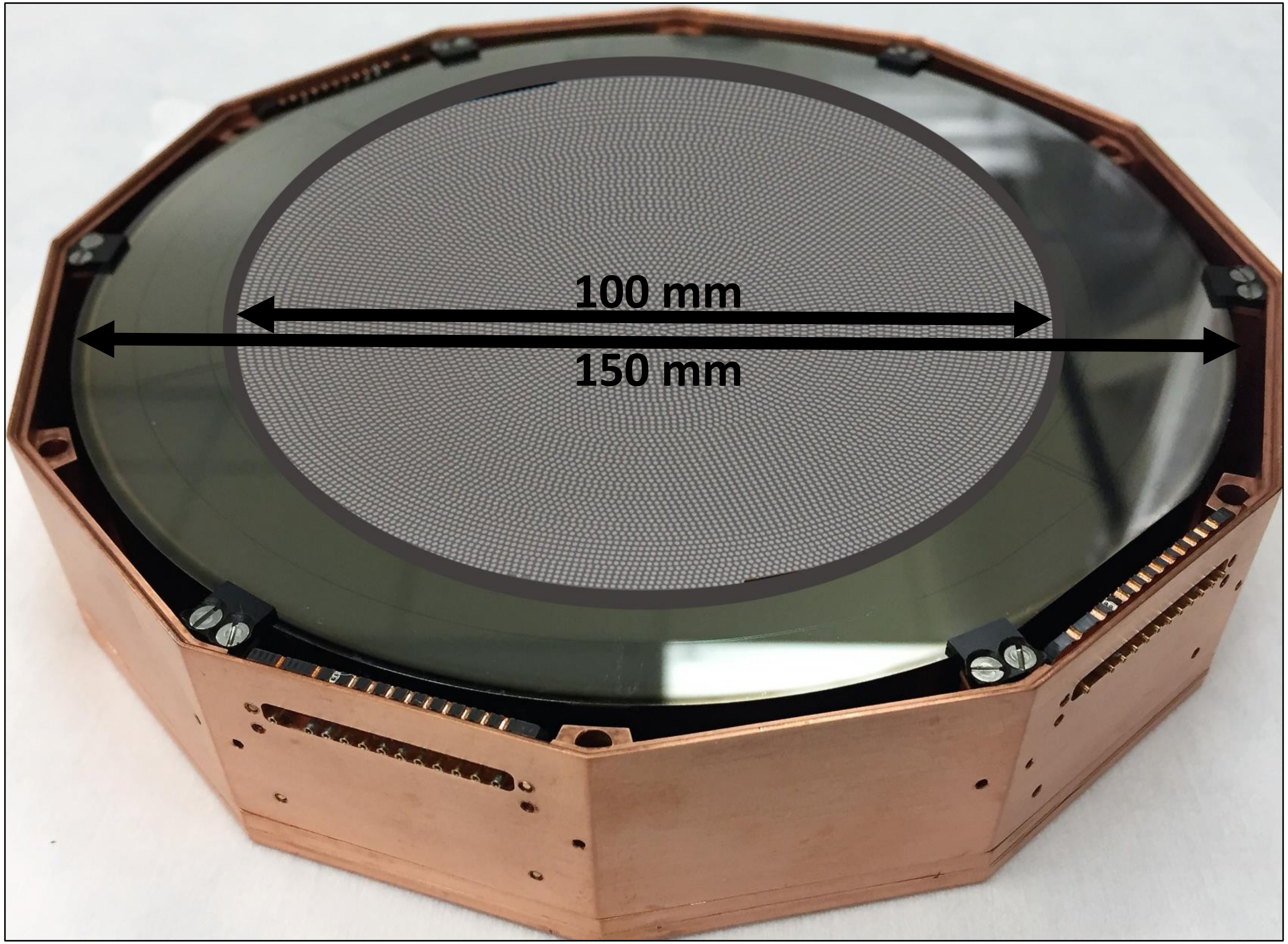
^{210}Pb on Detector Sidewalls

- Previous science reach limitations prompted a detailed study into the effects of various 210Pb contamination on detector sidewalls
- Method to reduce contamination proven effective but has some limitations
- Active tagging of decay products can be used when contamination levels would otherwise be deemed unacceptable

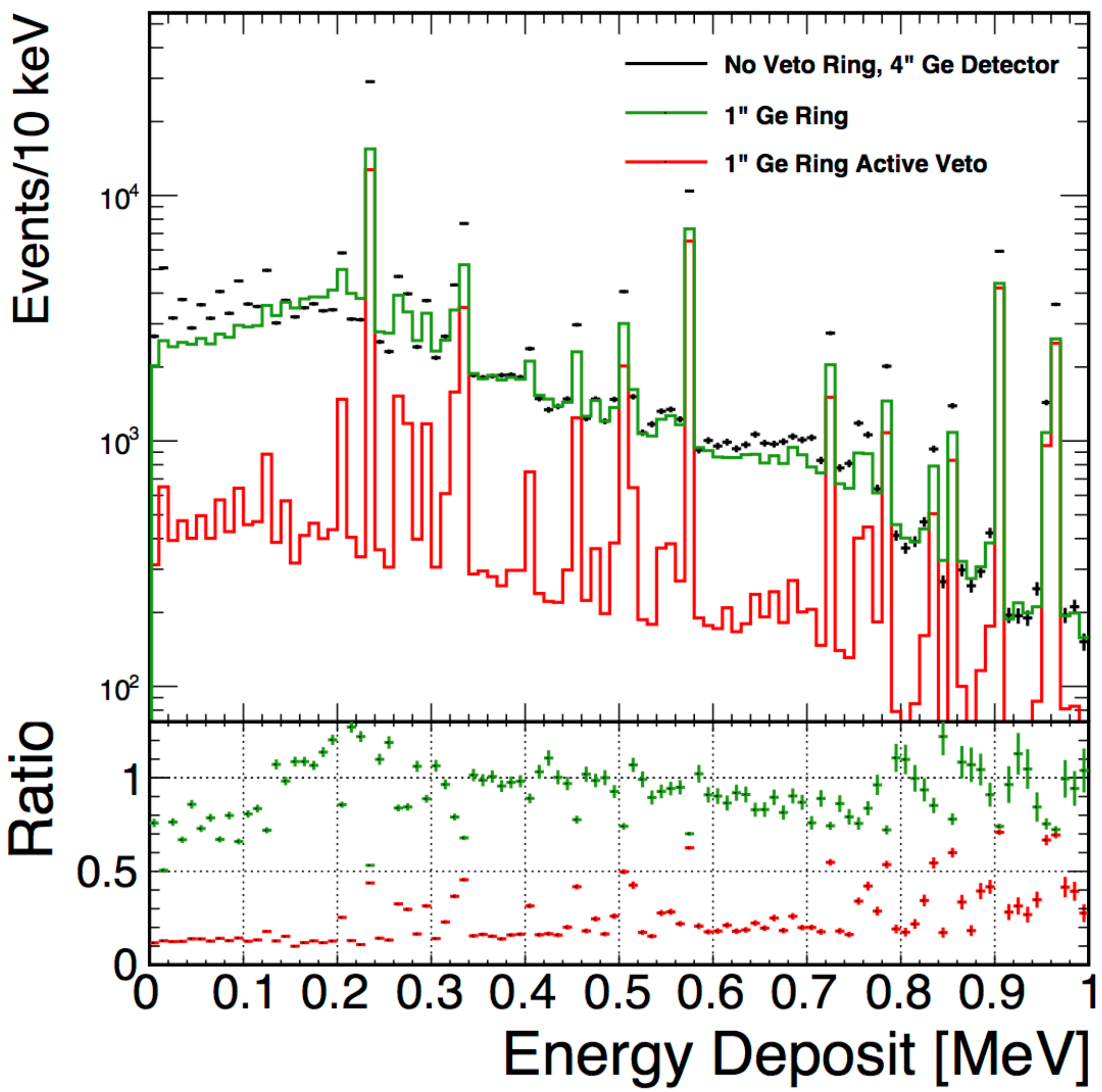


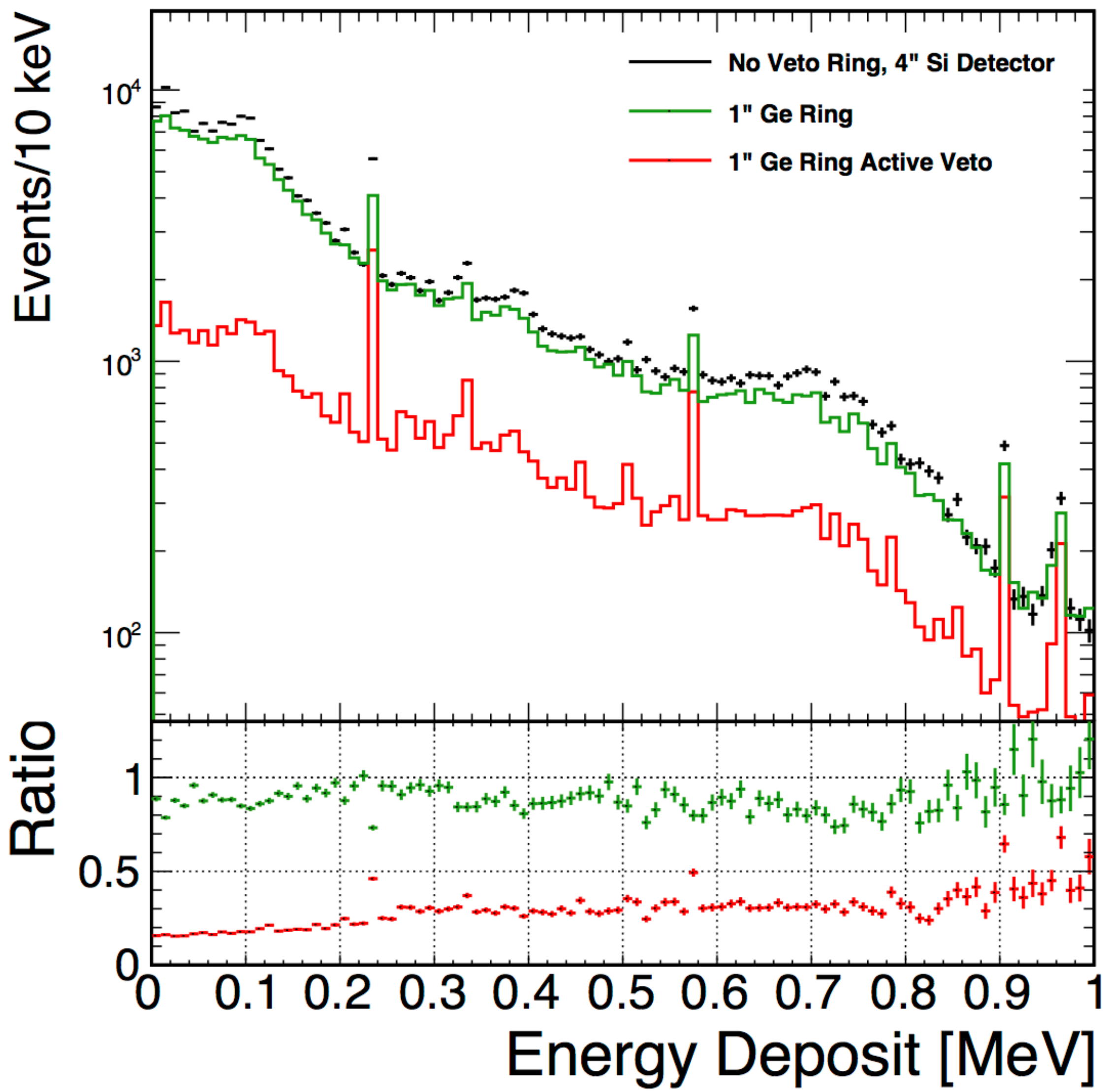


Initial Investigations

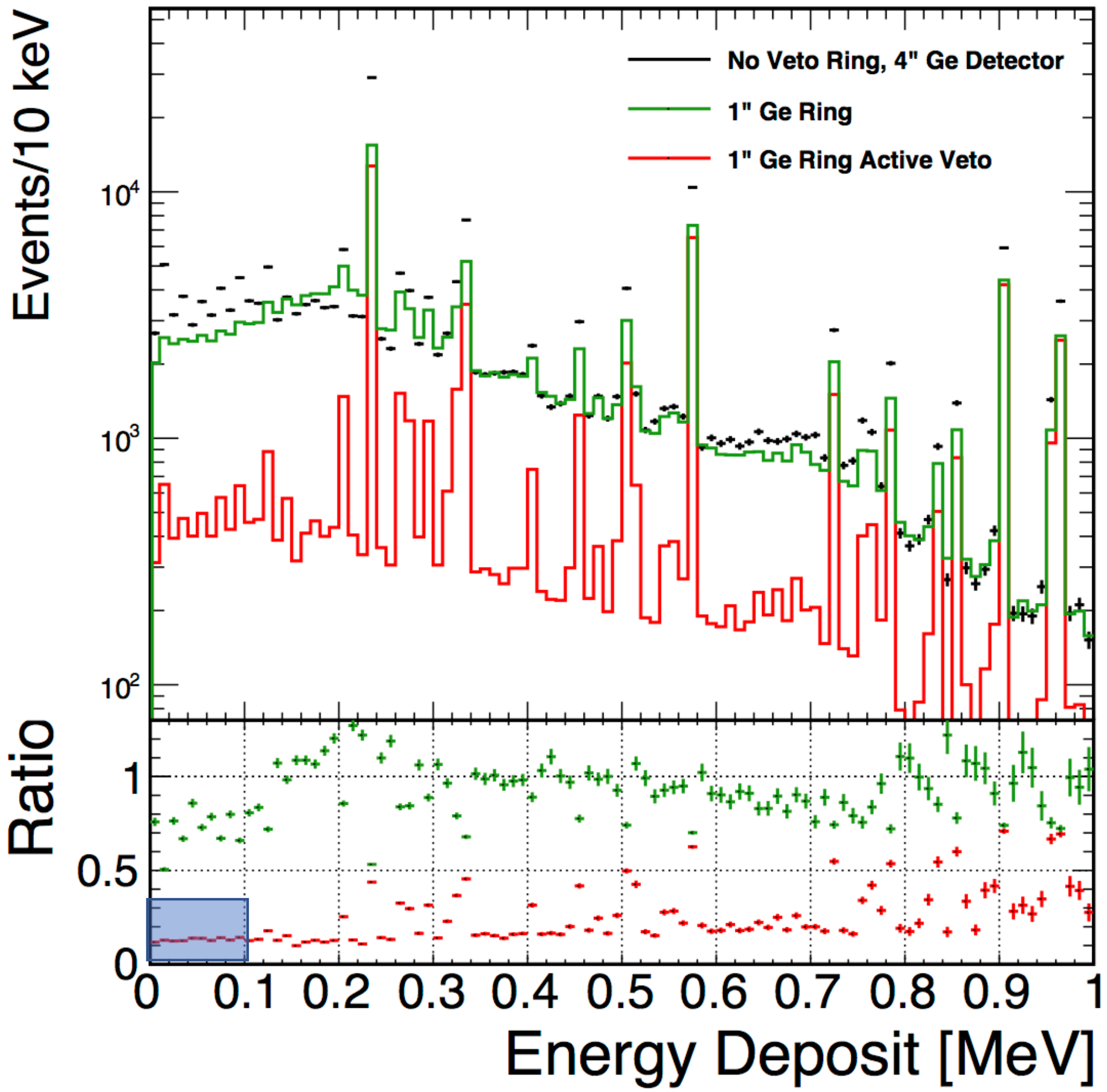


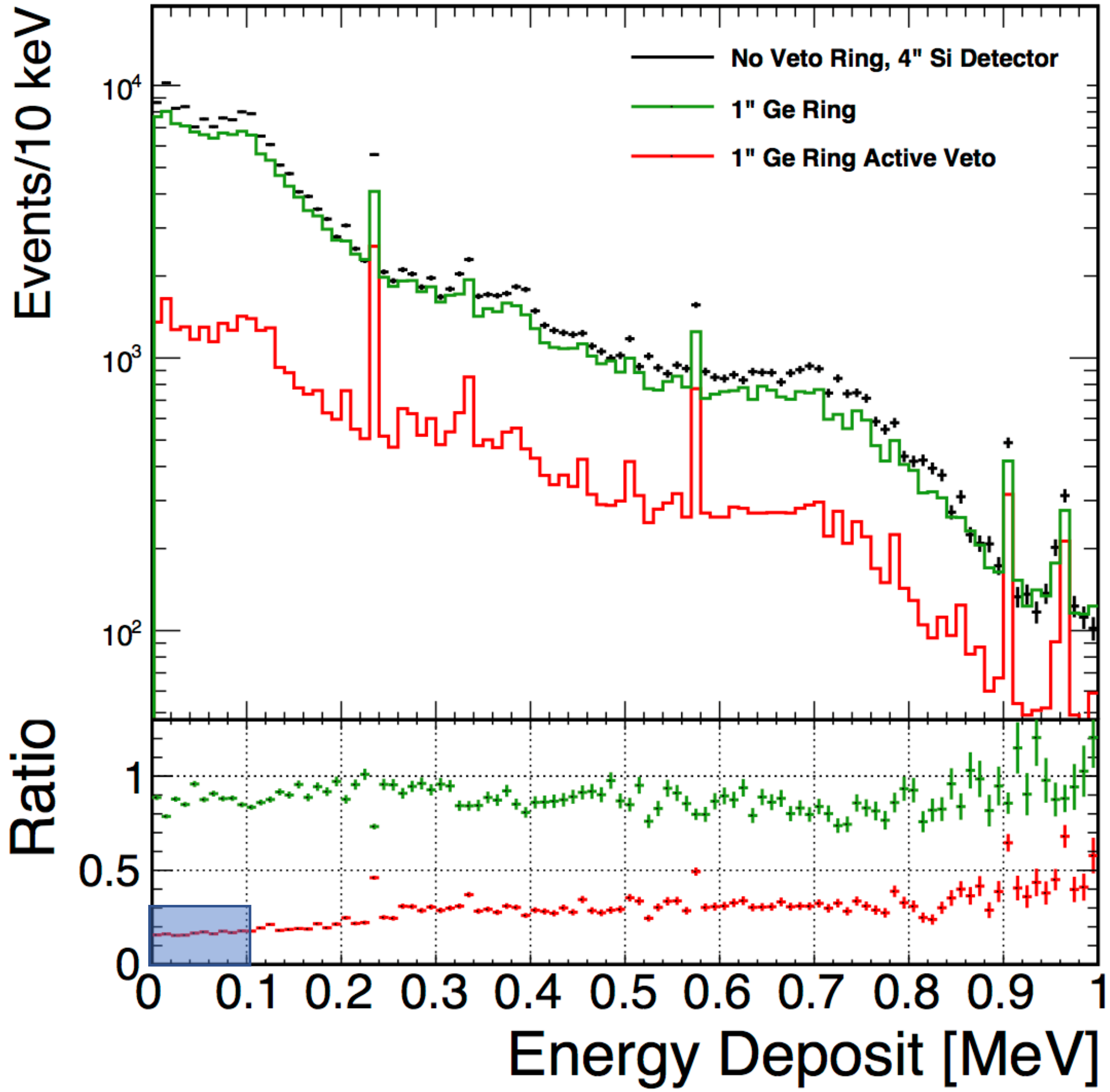
Compton Simulations



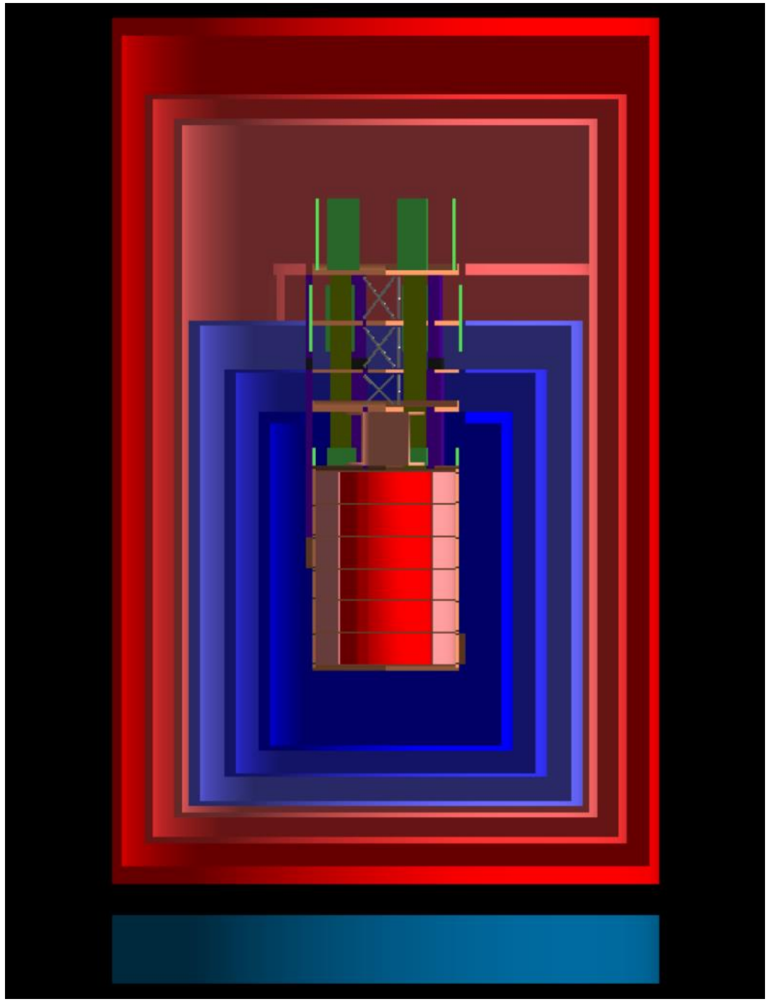


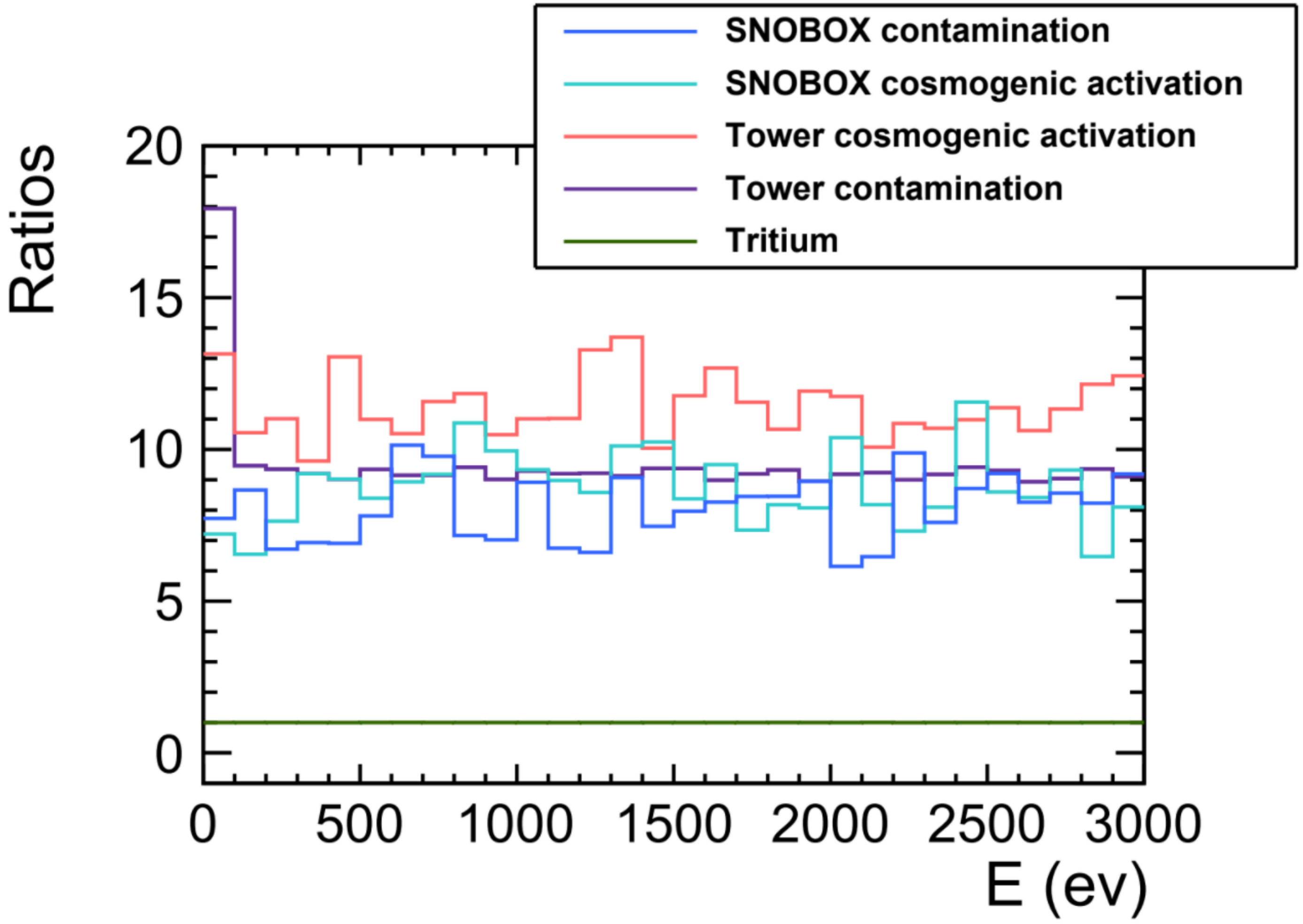
Compton Simulations





SCDMS SNOLAB-Specific Simulations

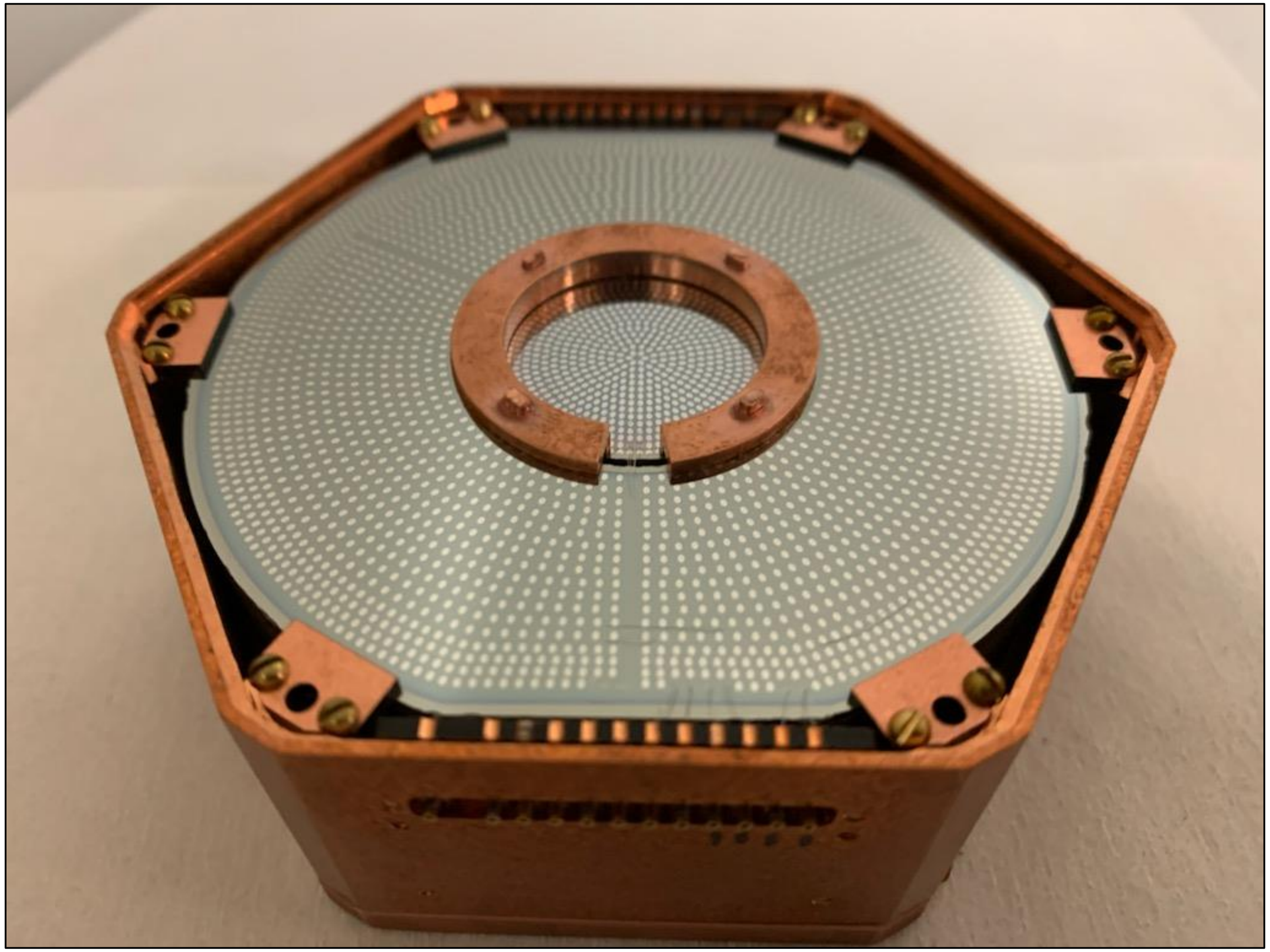




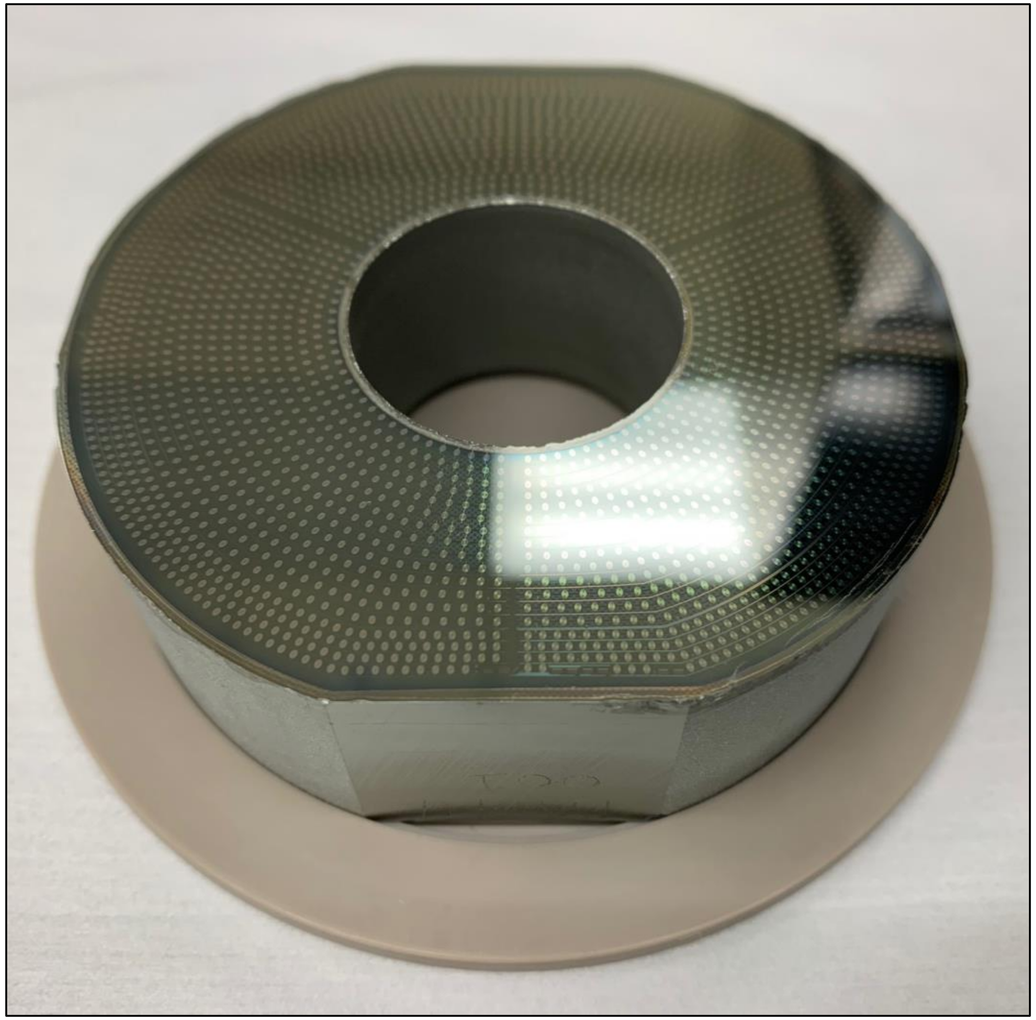
Z. Hong 2017, SCDMS Collab Mtg. Document

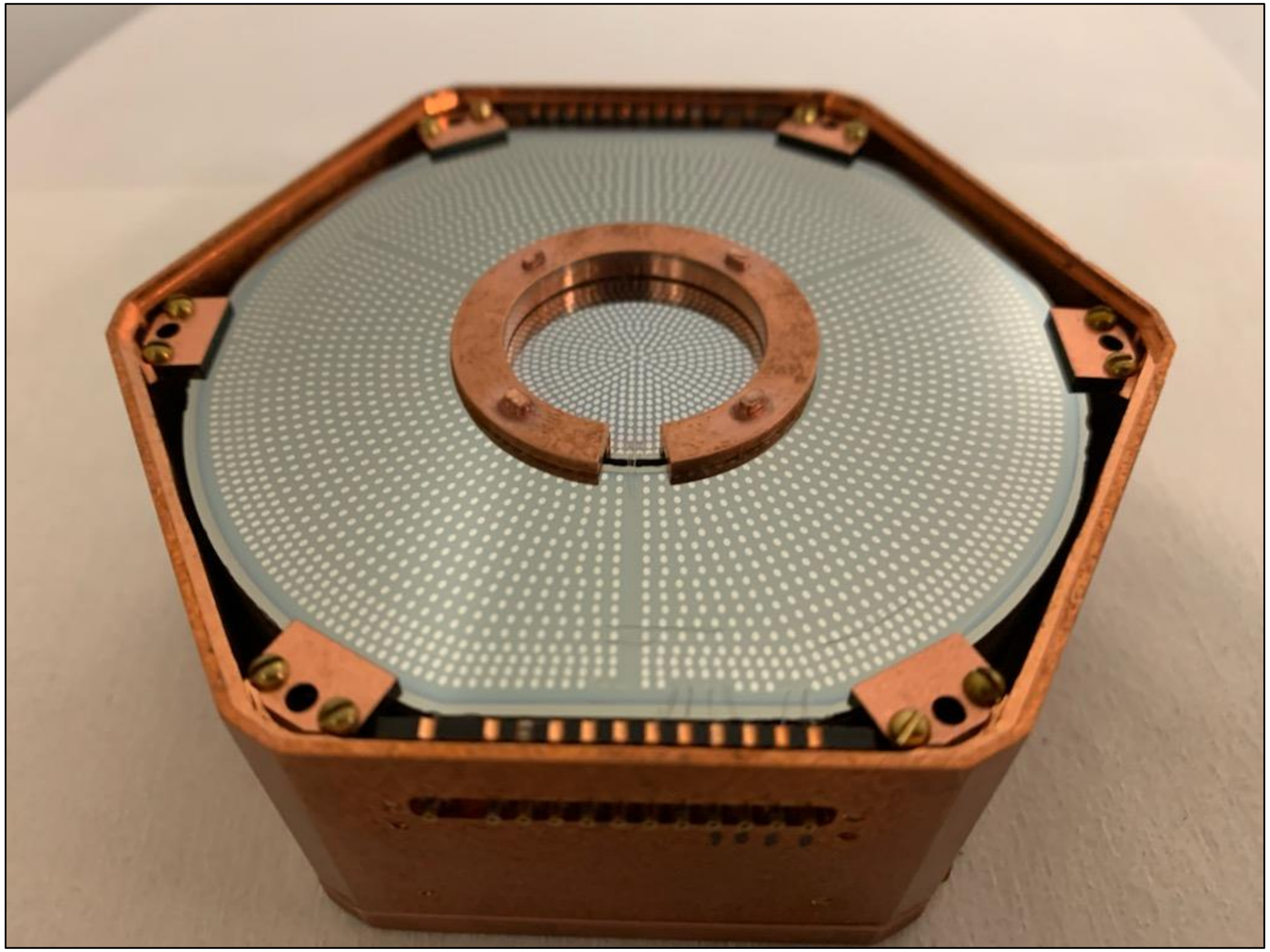
Fabrication Hurdles

- Creating an annular substrate with optically polished surfaces
- Photolithography on an annular substrate
- Mounting and wiring the inner detector



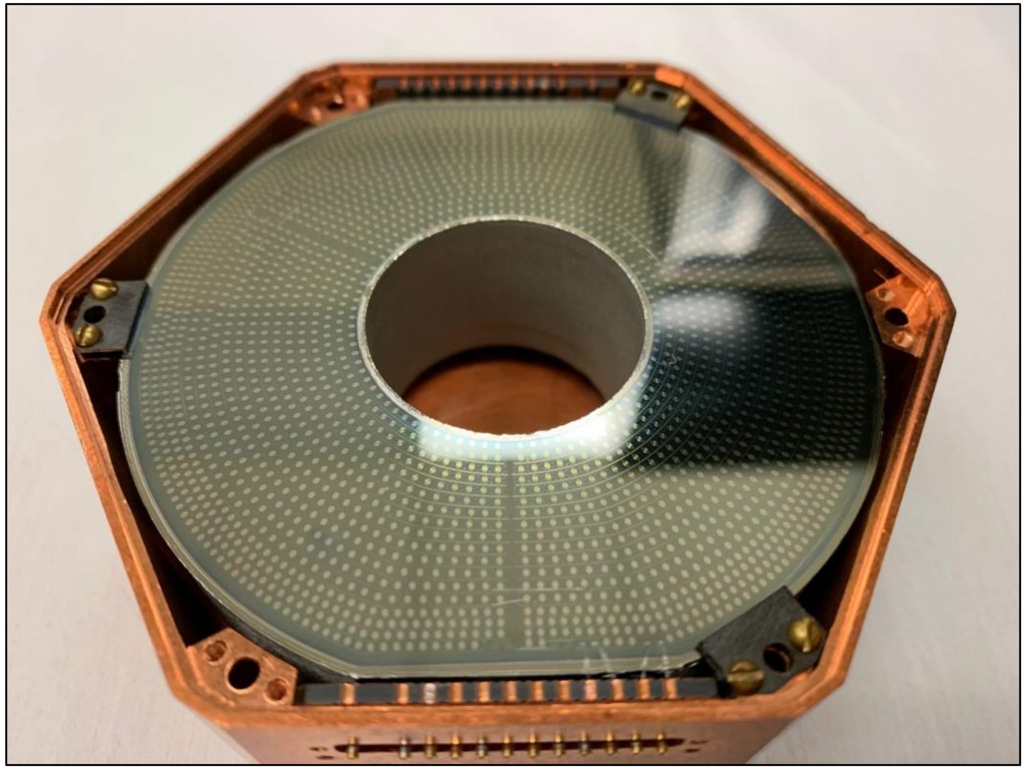
Fabrication Hurdles

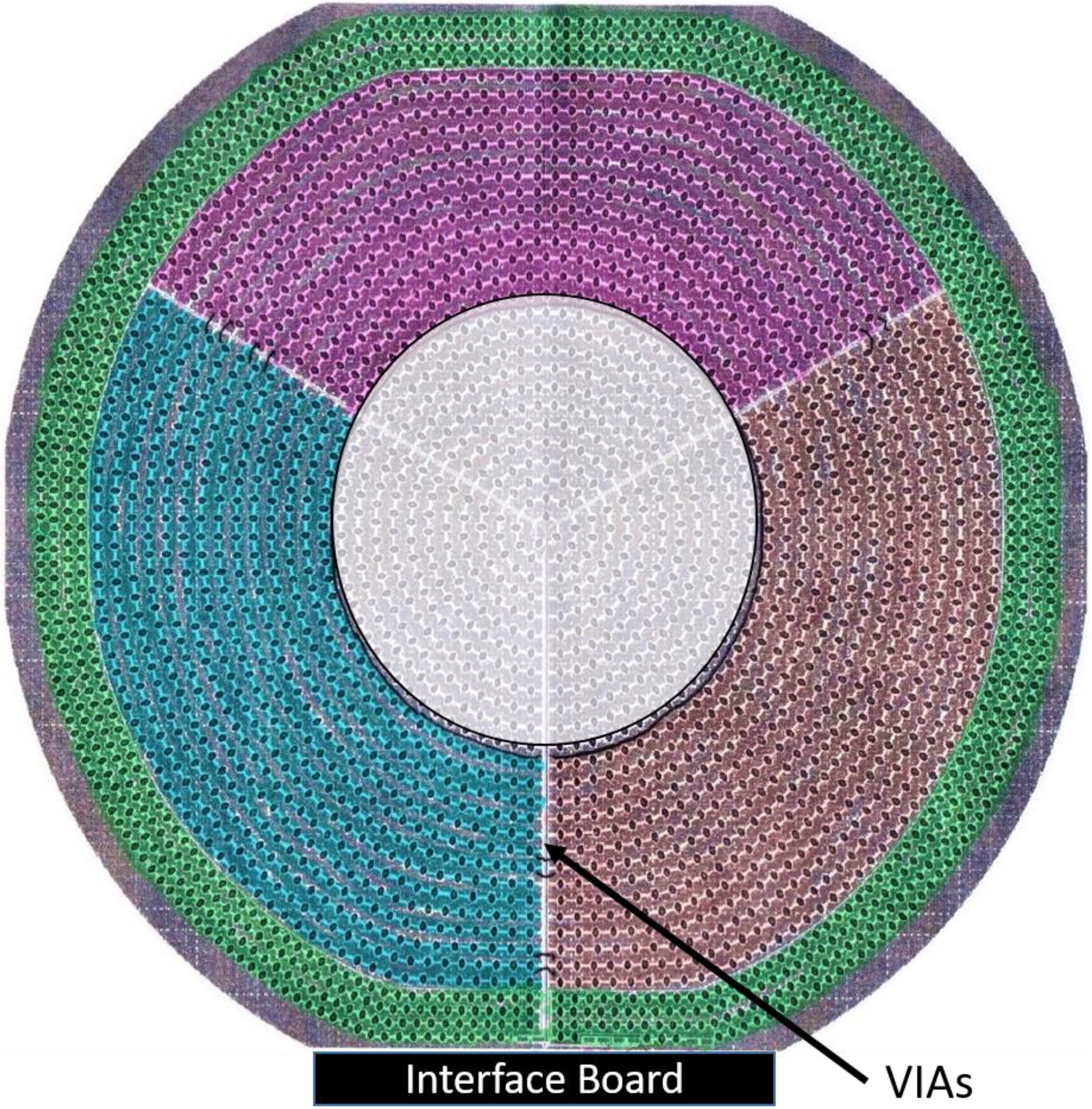




Prototype “Donut”

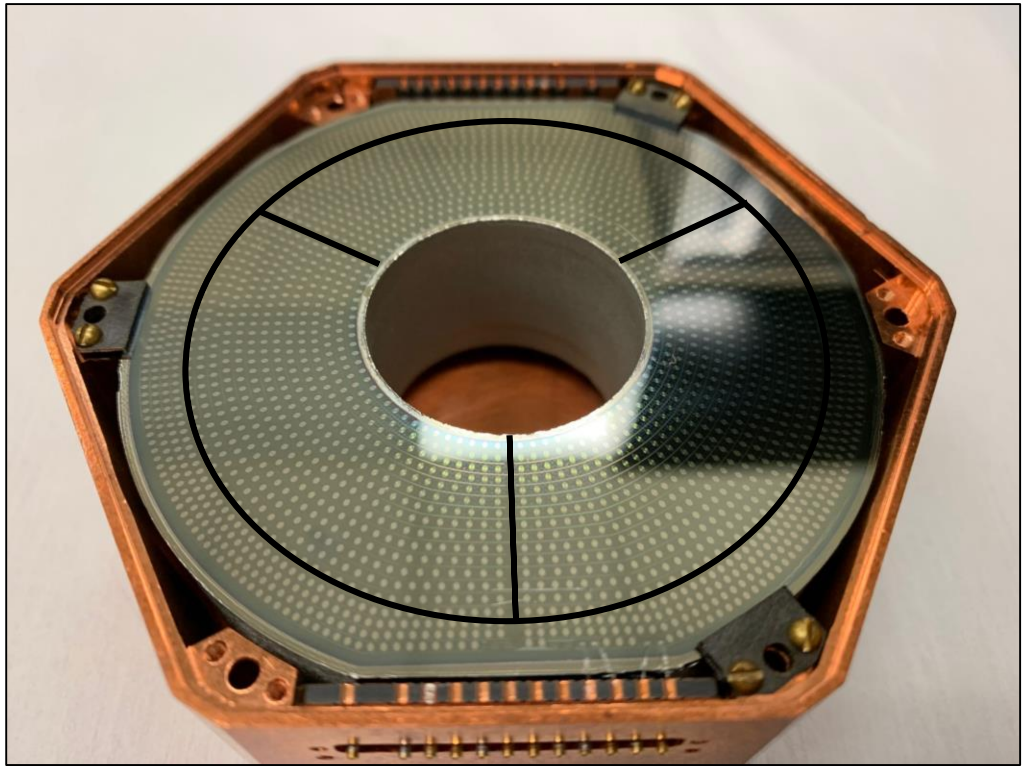
- Used an existing “HV”mask
- Green = “outer veto channel”
- Remaining three are combined into “inner veto channel”

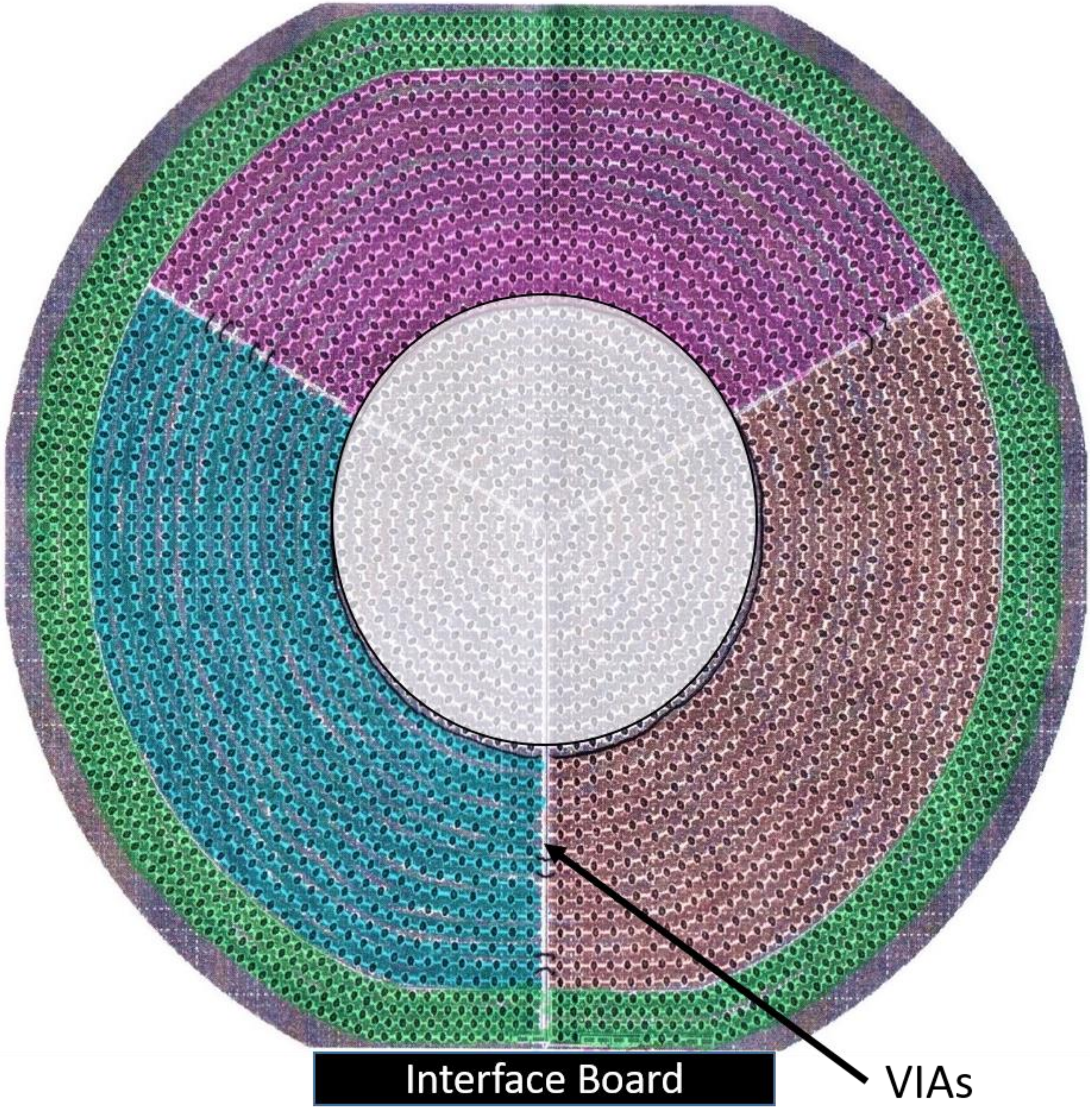




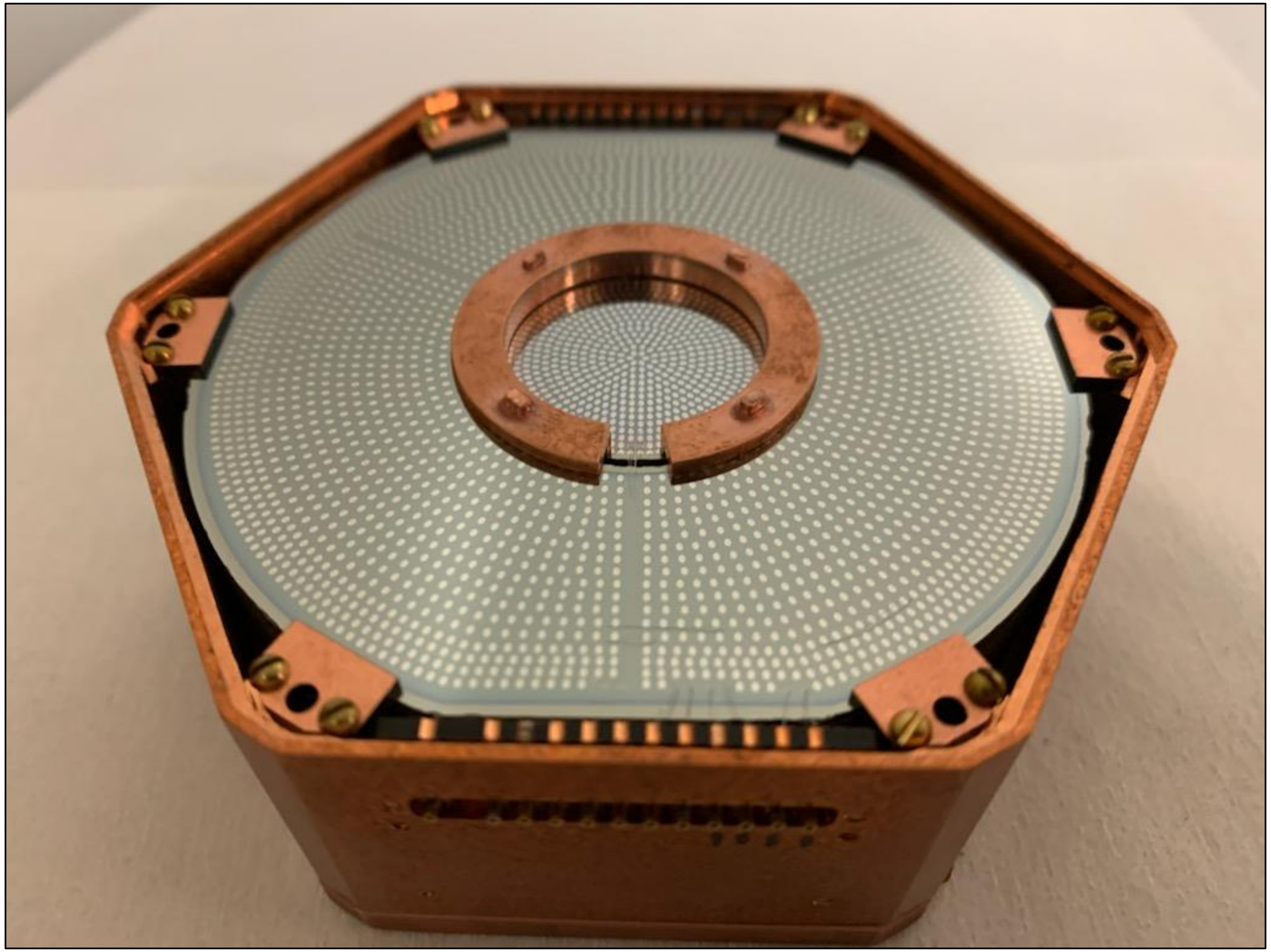
Prototype “Donut”

- Used an existing “HV”mask
- Green = “outer veto channel”
- Remaining three are combined into “inner veto channel”

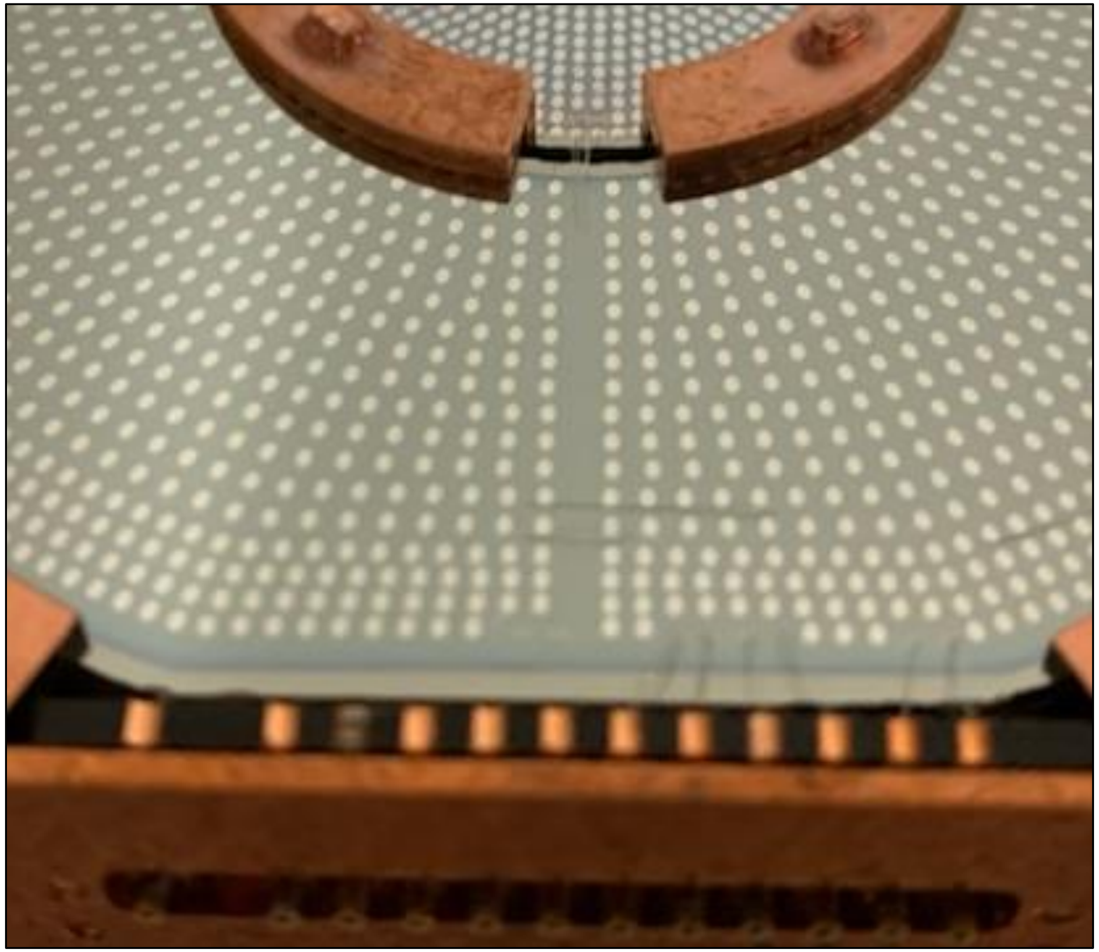


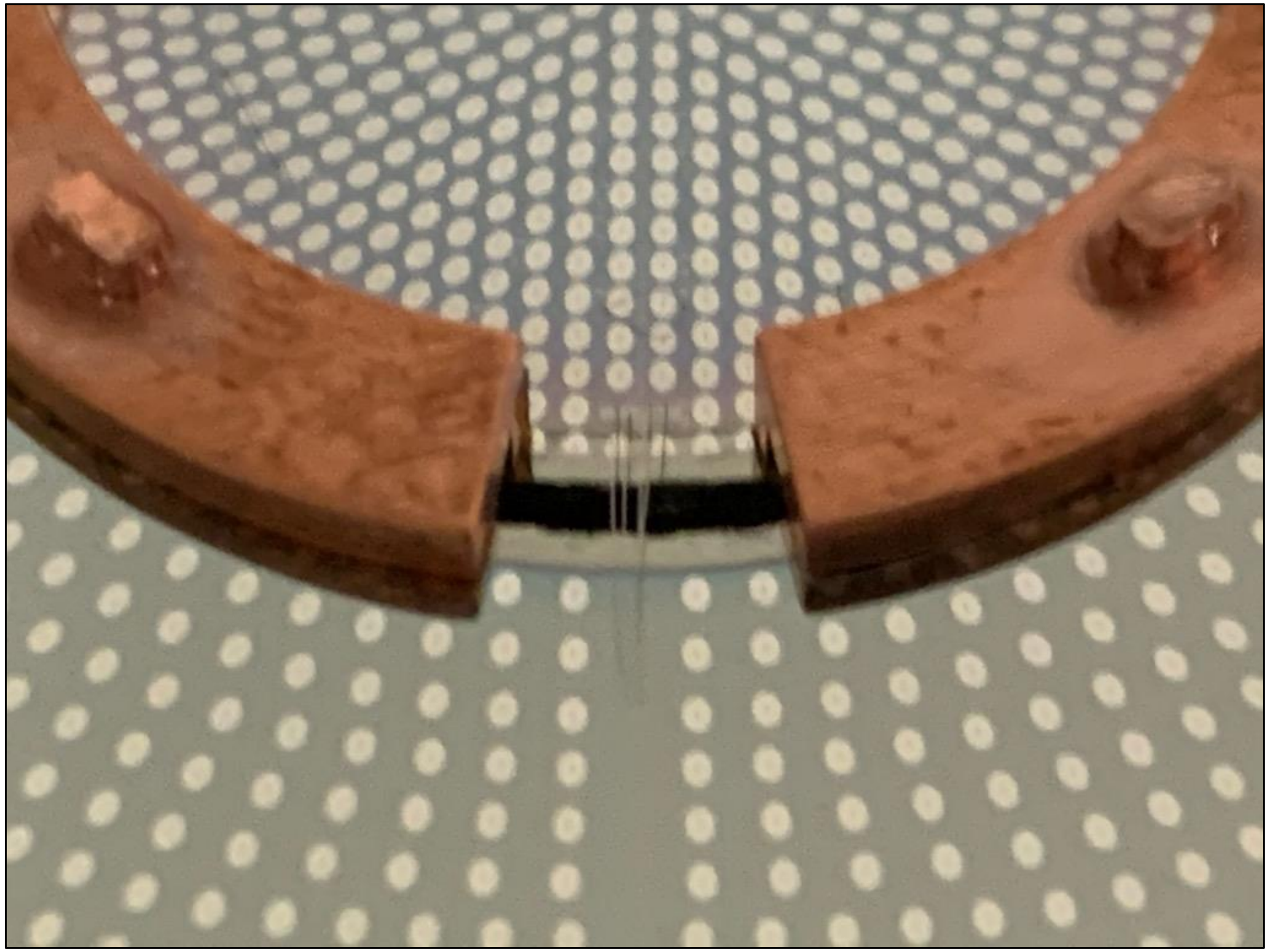


25mm Diameter (4mm thick) Inner Detector

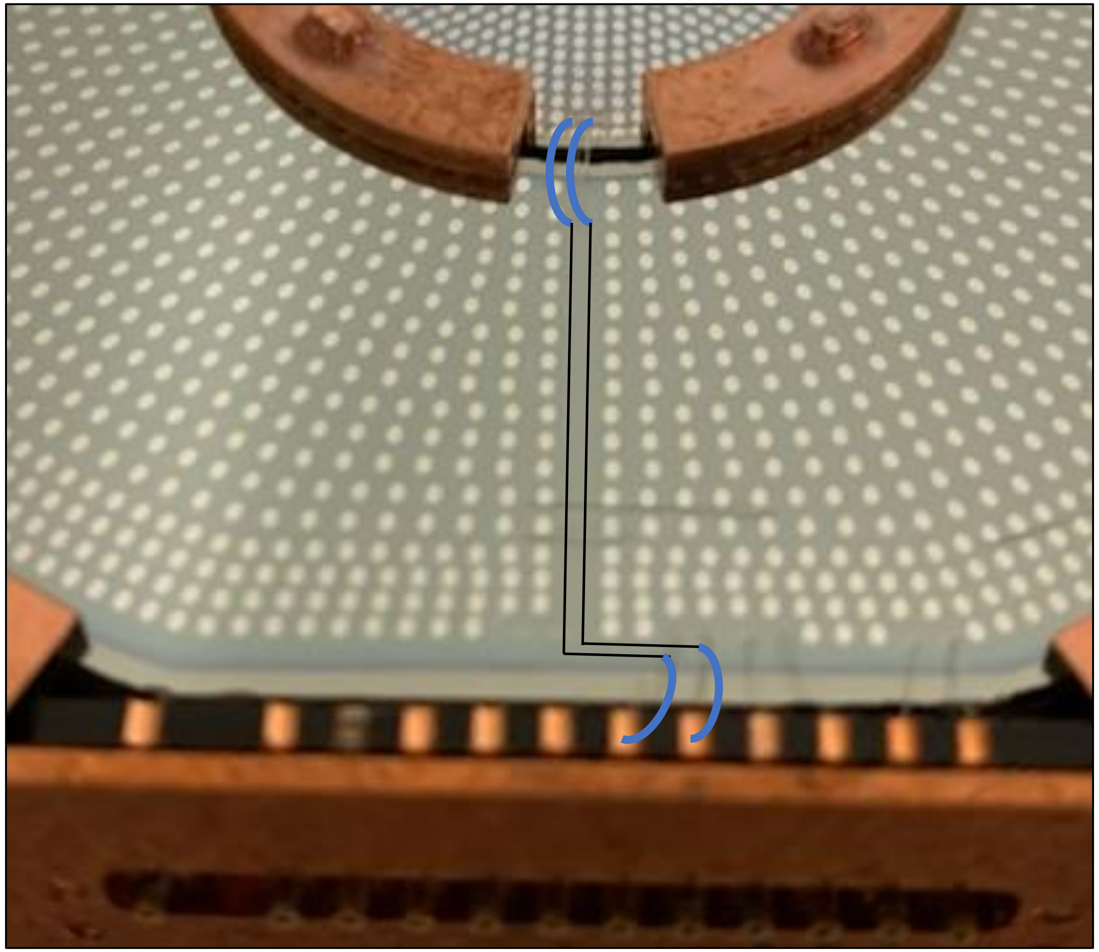


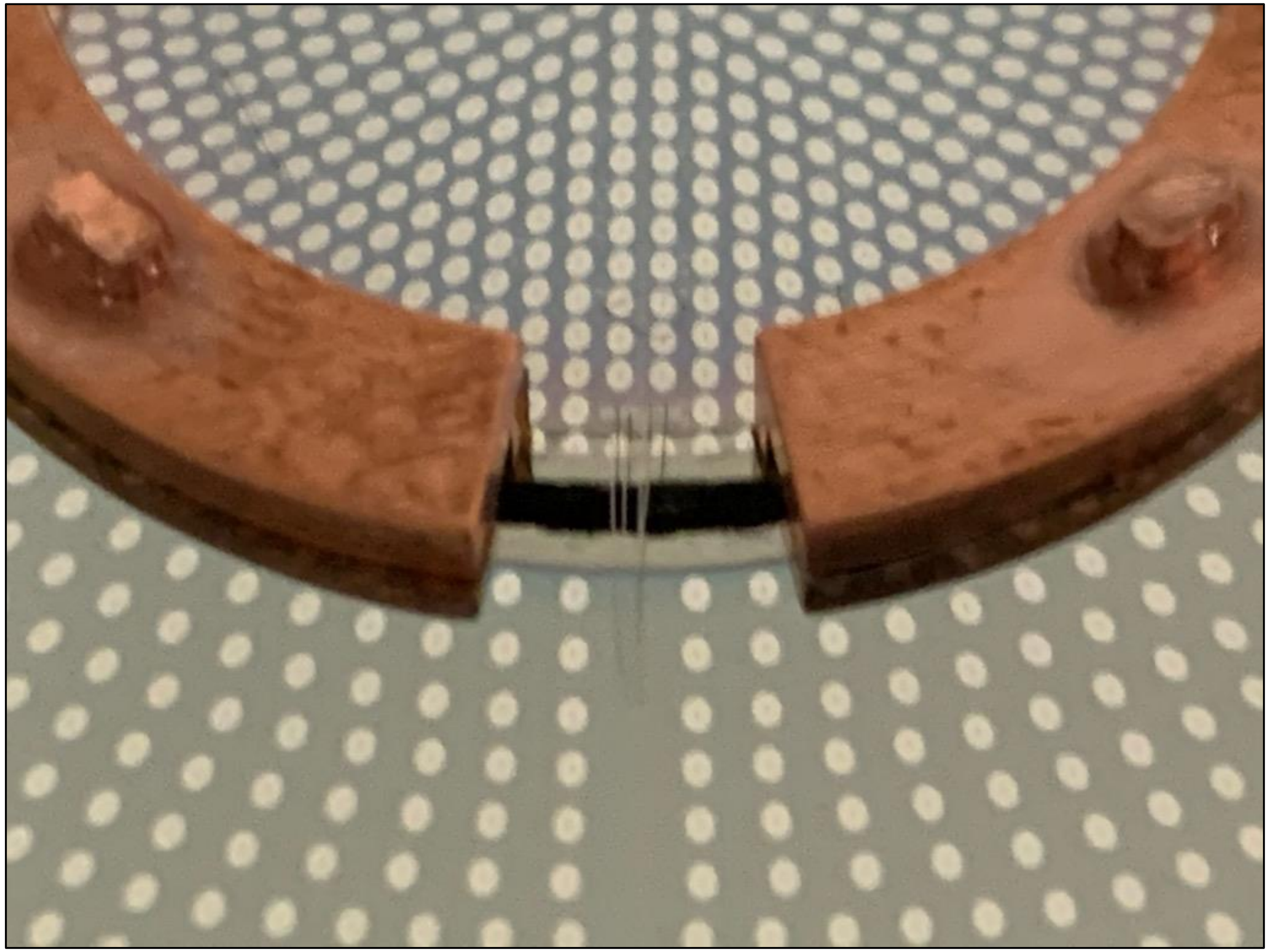
Inner Detector Wired to Electronics via Outer Detector





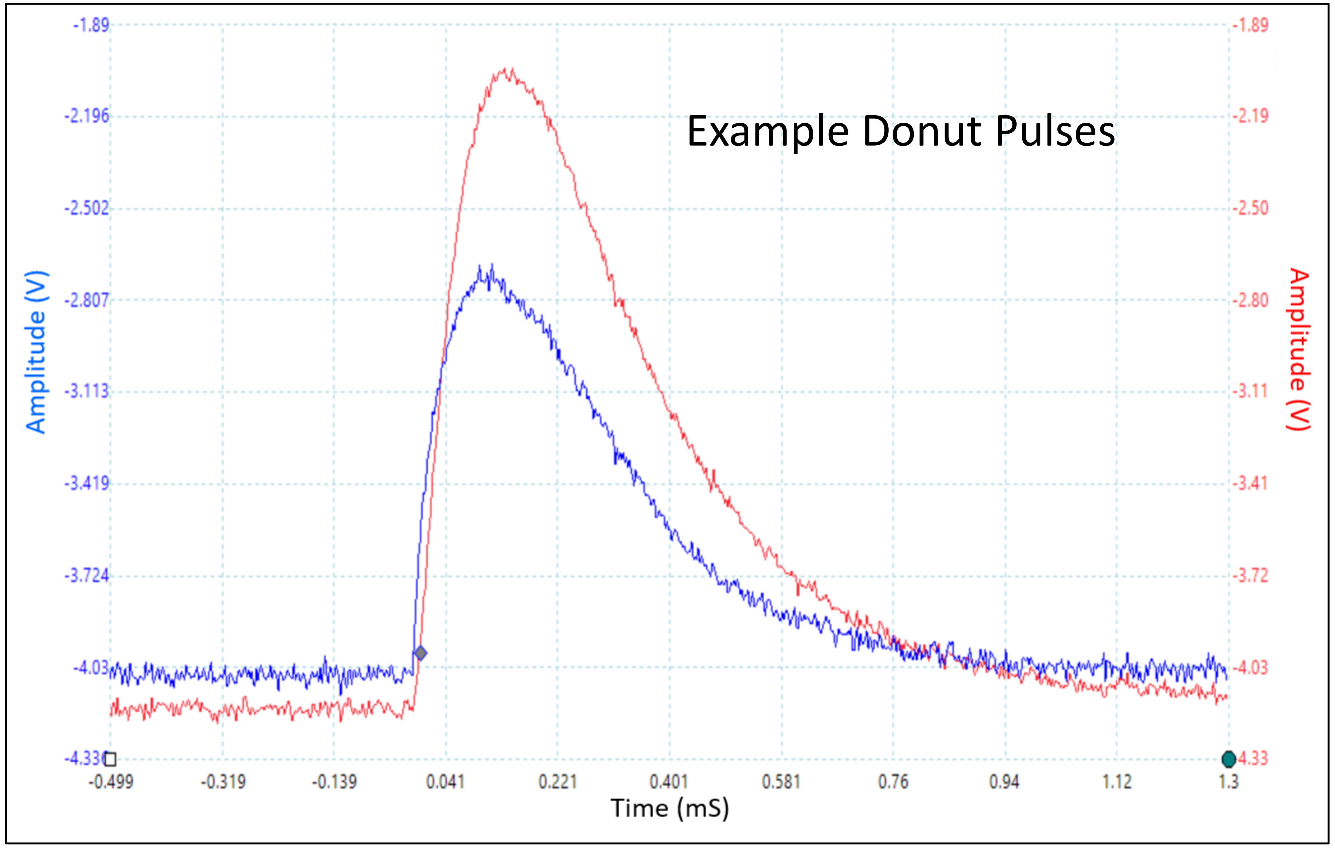
Inner Detector Wired to Electronics via Outer Detector

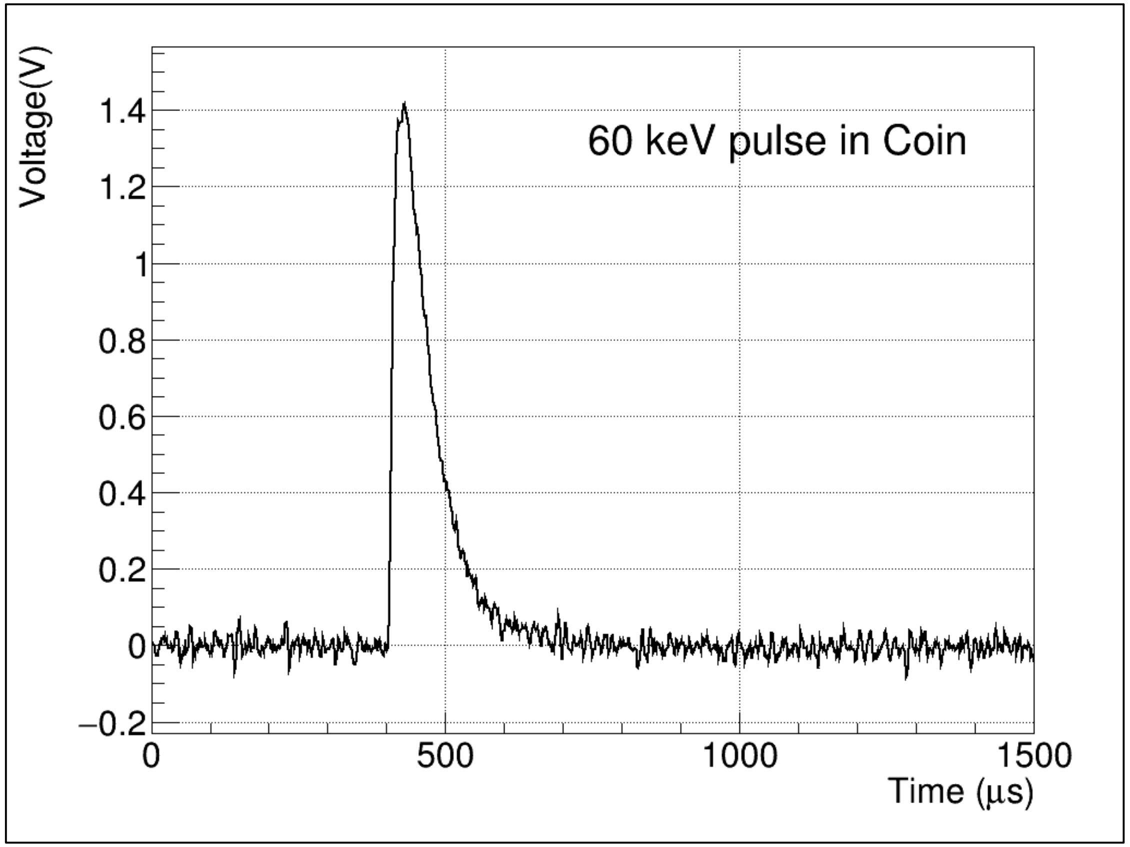




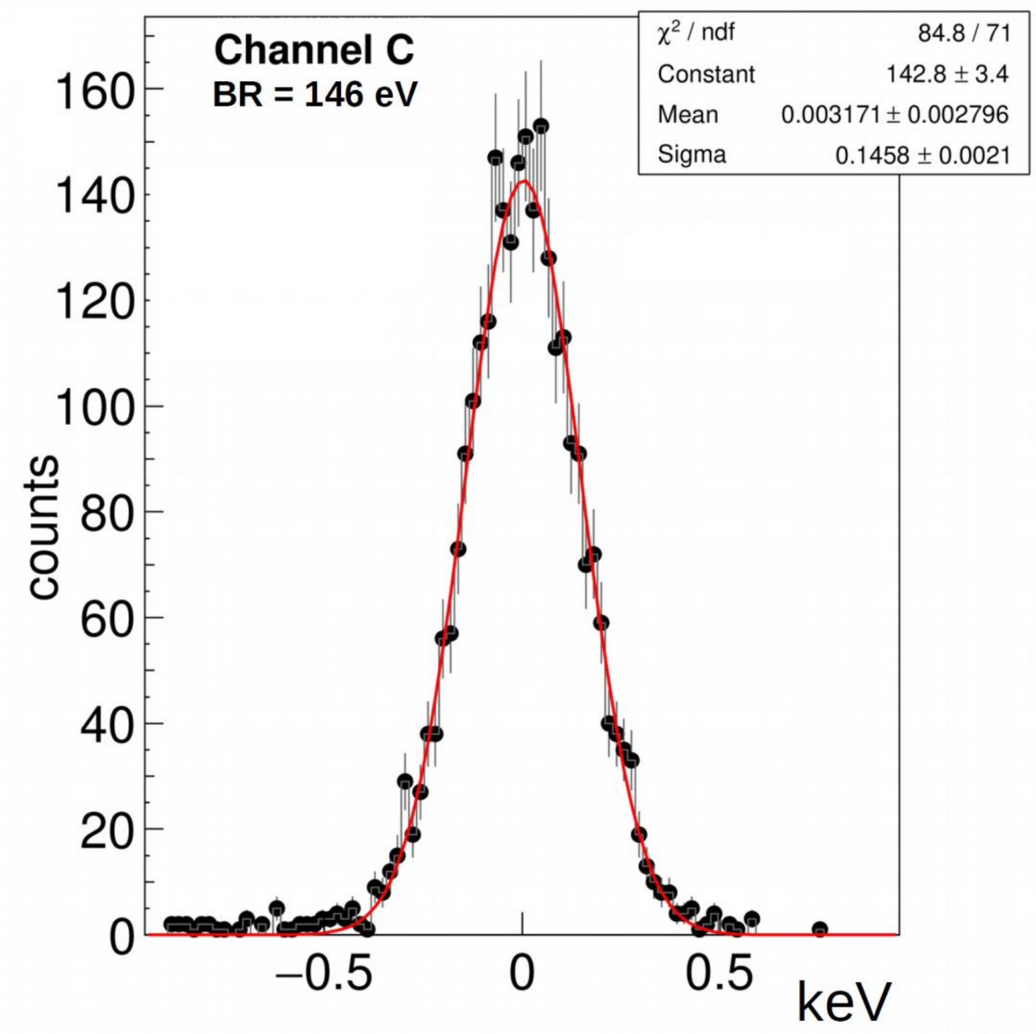
Blue – Wirebonds
Black – Electrodes patterned on detector

First Light

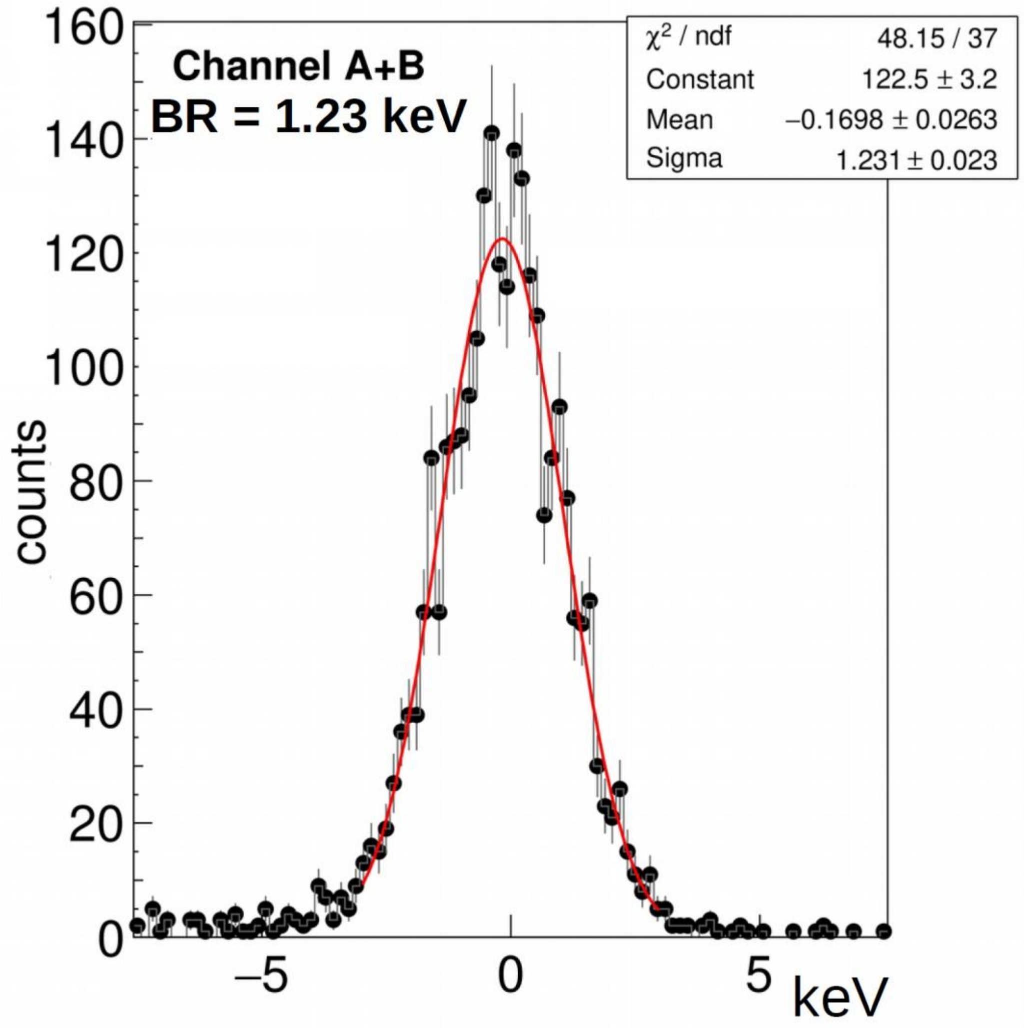

Example Donut Pulses
Amplitude (V)
Amplitude (V)
Time (mS)
-1.89
-2.196
-2.502
-2.807
-3.113
-3.419
-3.724
-4.03
-4.33
-2.19
-2.50
-2.80
-3.11
-3.41
-3.72
-0.499
-0.319
-0.139
0.041
0.221
0.401
0.581
0.76
0.94
1.12
1.3


60 keV pulse in Coin
Voltage(V)
Time (µs)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
−0.2
0
500
1000
1500

Performance – Baseline Resolution at 0V

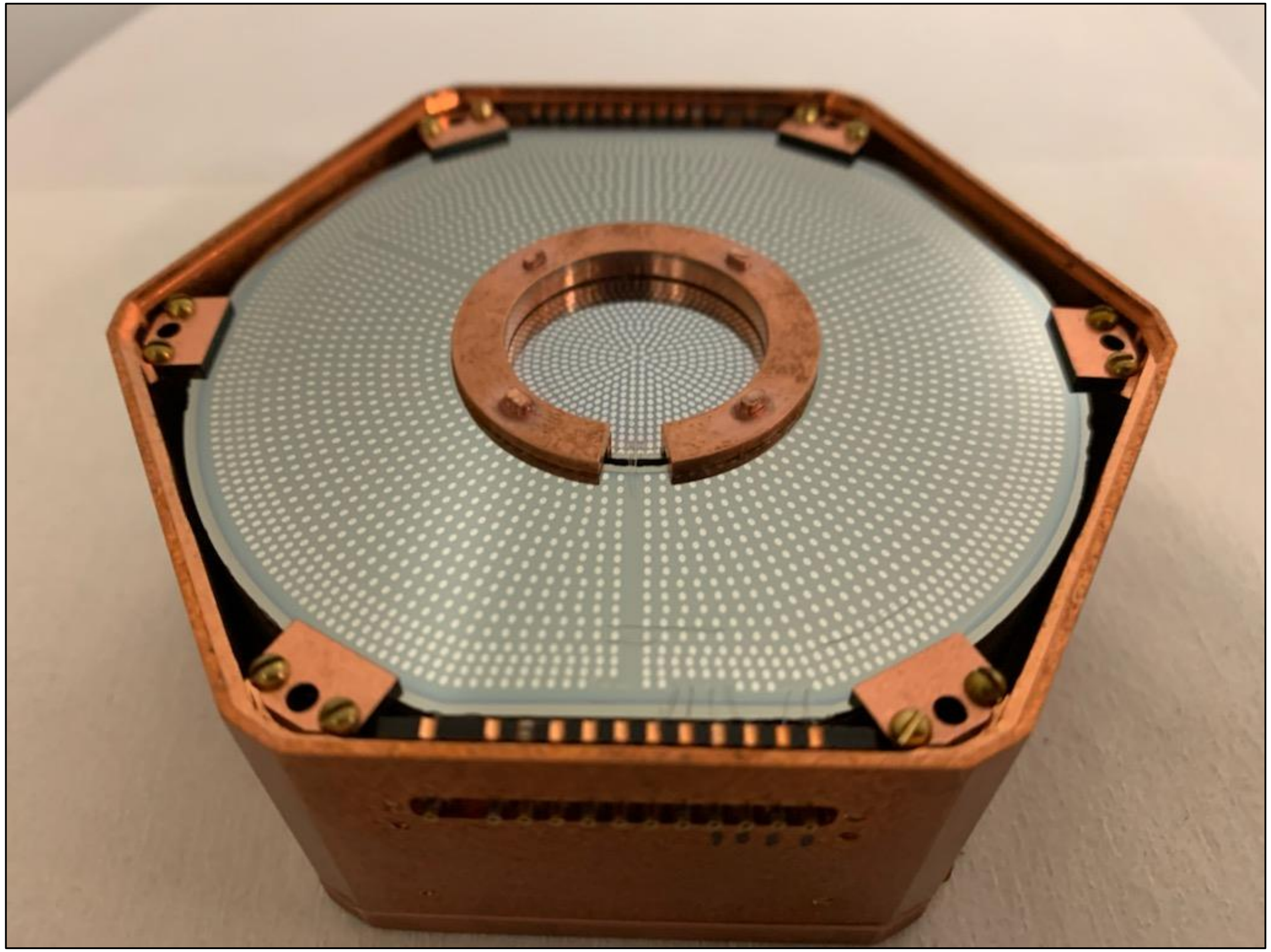


Inner Detector BR

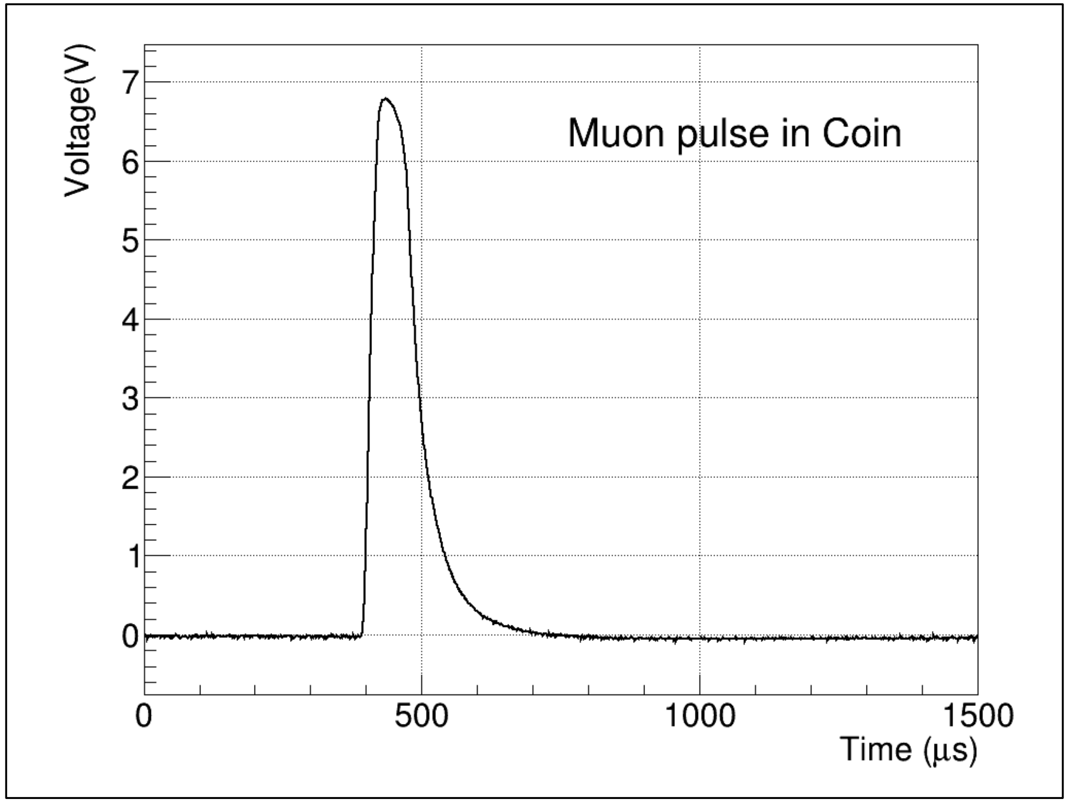


Veto Detector BR

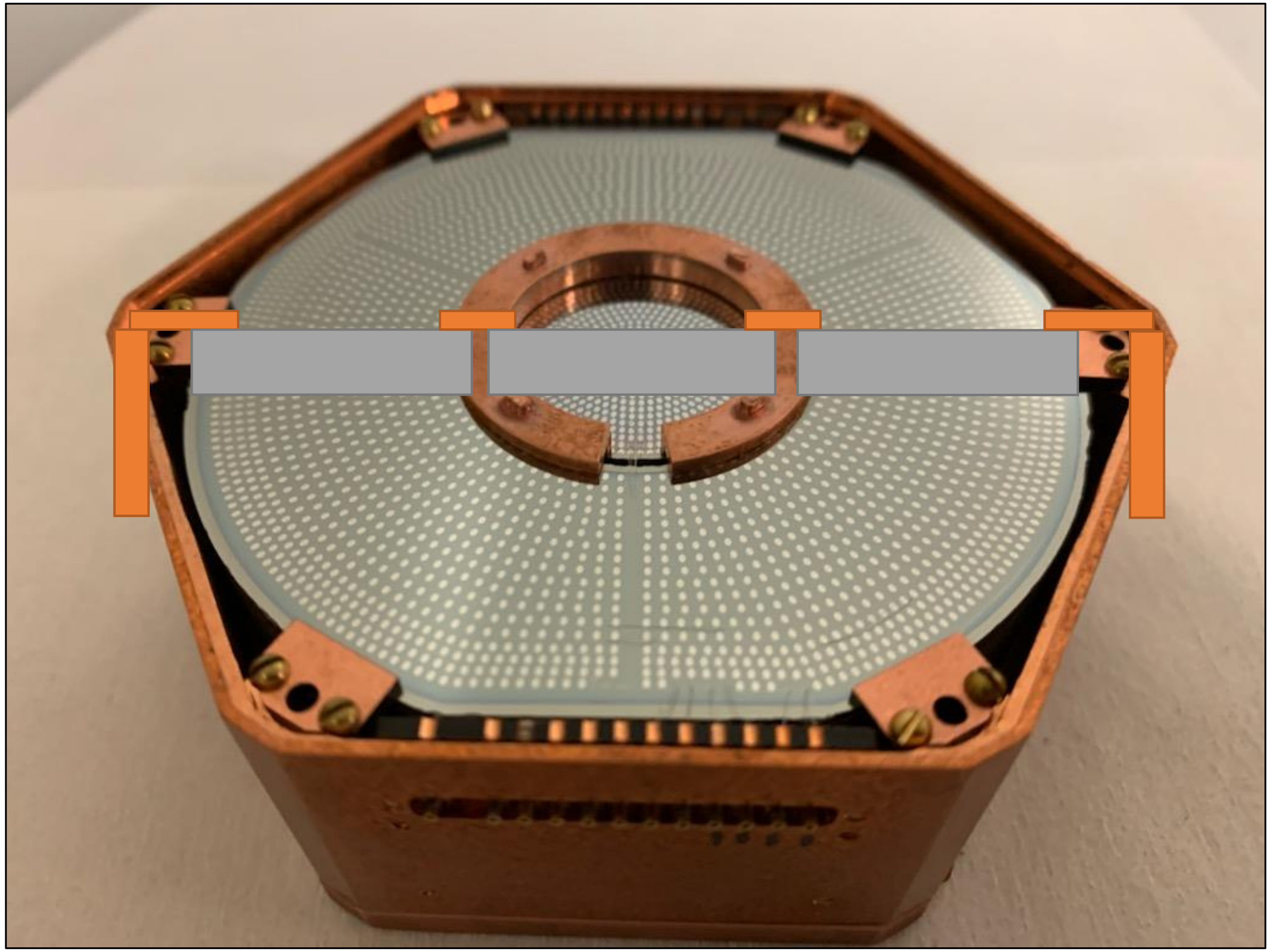
Thermal Performance



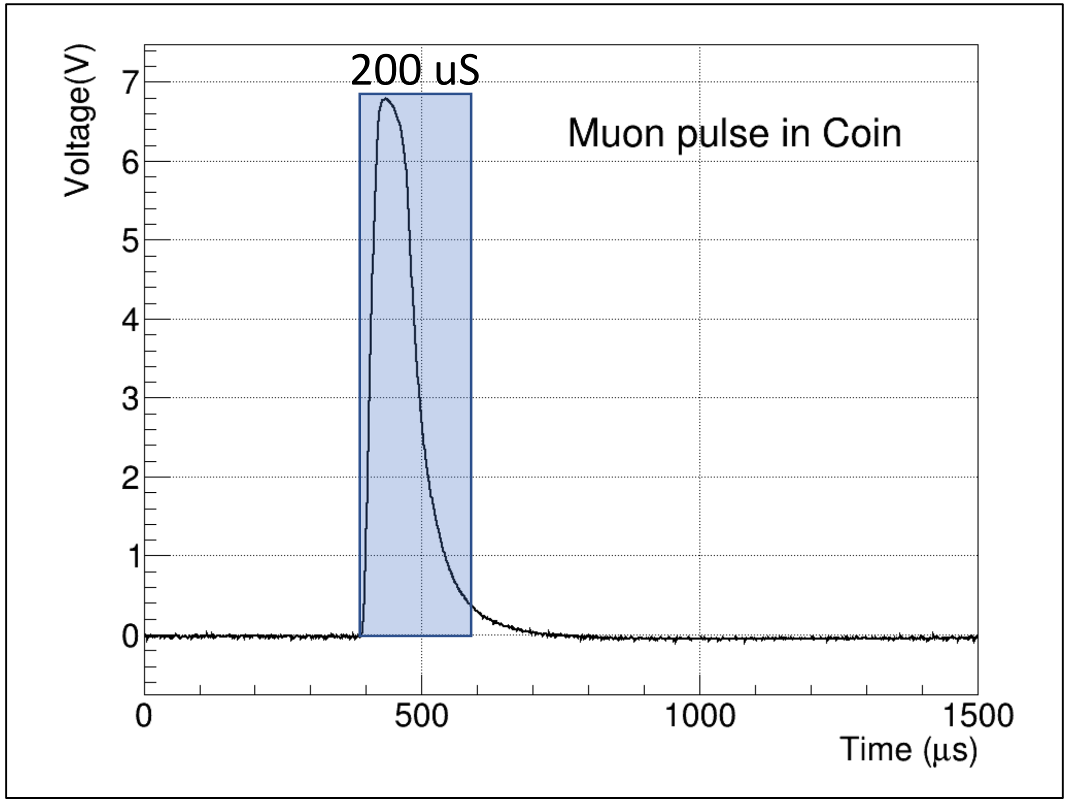
Housing → Clamp → Ge outer → Clamp → Ge inner



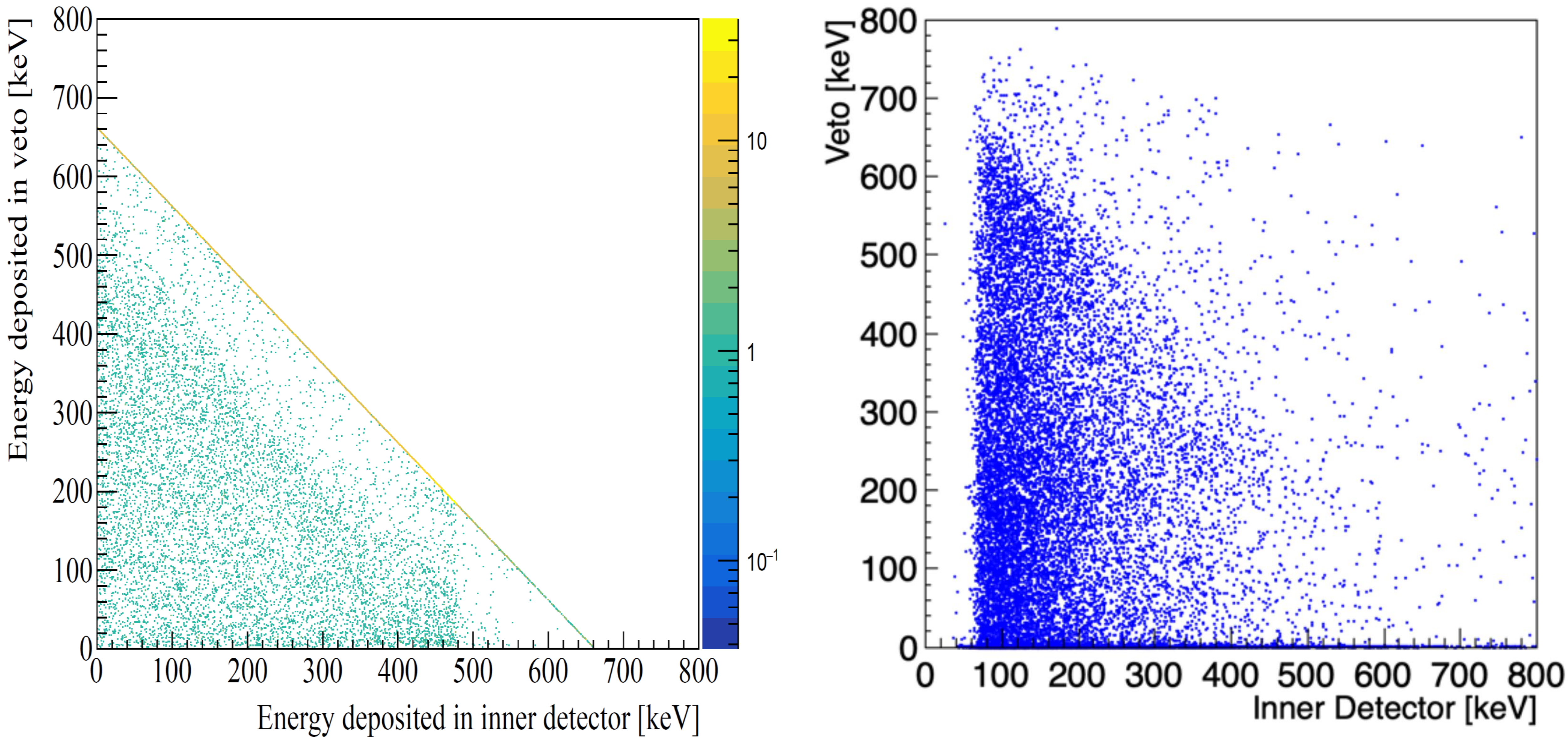
Thermal Performance



Housing → Clamp → Ge outer → Clamp → Ge inner



^{137}Cs (662 keV) Compton Study



Future Work

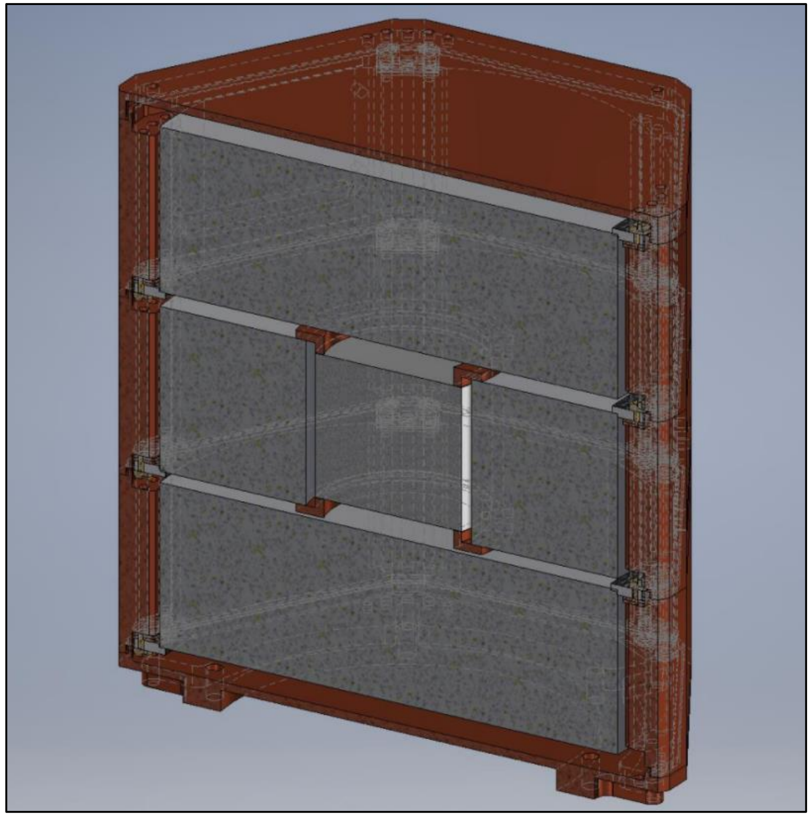
MONTH DAY YEAR HOUR MIN
JUL 05 2010 AM PM 01:21
DESTINATION TIME
MONTH DAY YEAR HOUR MIN
OCT 26 AM PM 01:22
PRESENT TIME
MONTH DAY YEAR HOUR MIN
OCT 26 1985 AM PM 01:20
LAST TIME DEPARTED

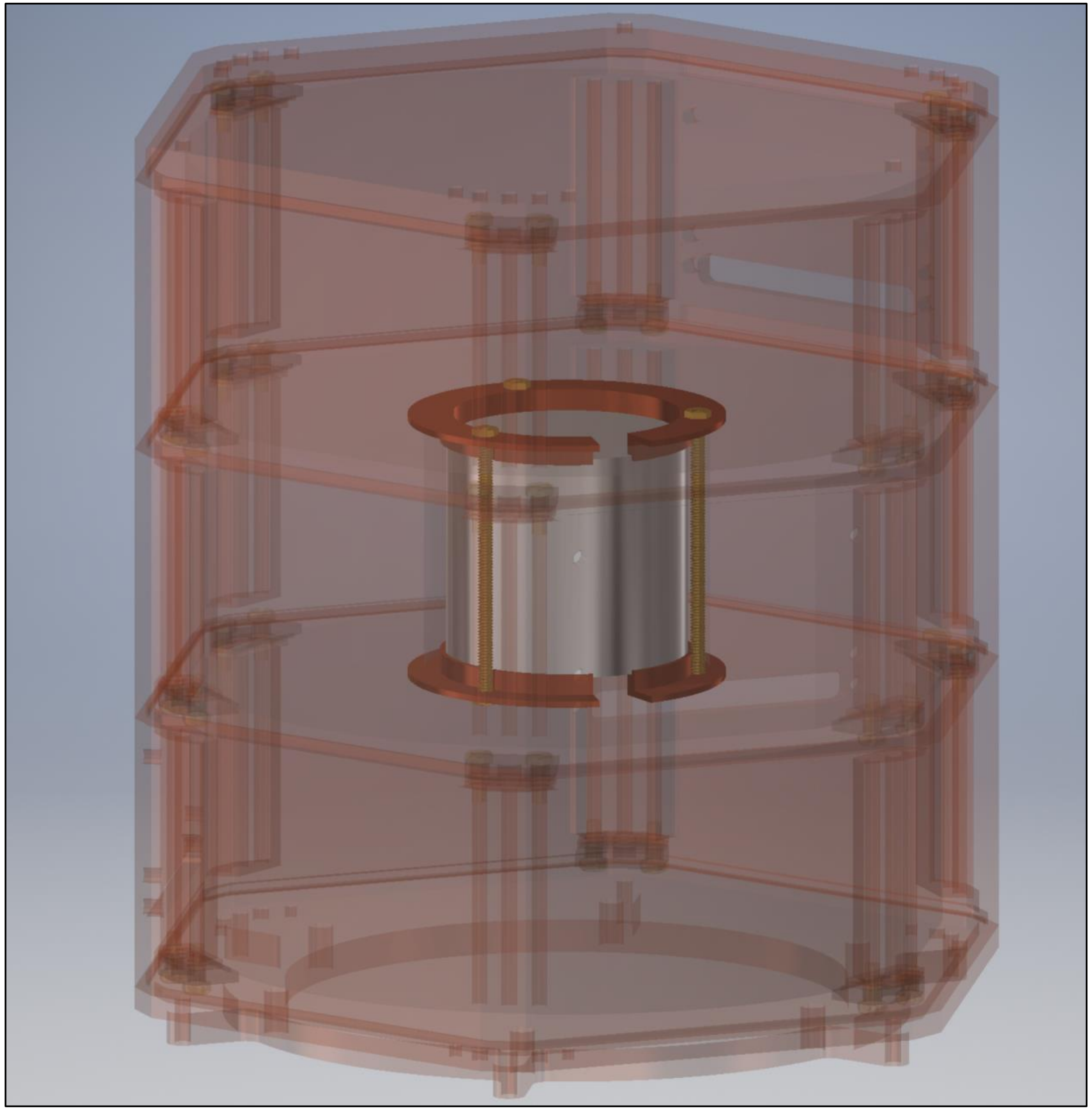
Future Work – Overall Design

- Improve detector-to-detector line of sight by reducing cross-section of internal mounting materials
- Design a more appropriate circuit/channel pattern for veto detector
- **Measure decay products from Radon plated inner detector sidewalls**

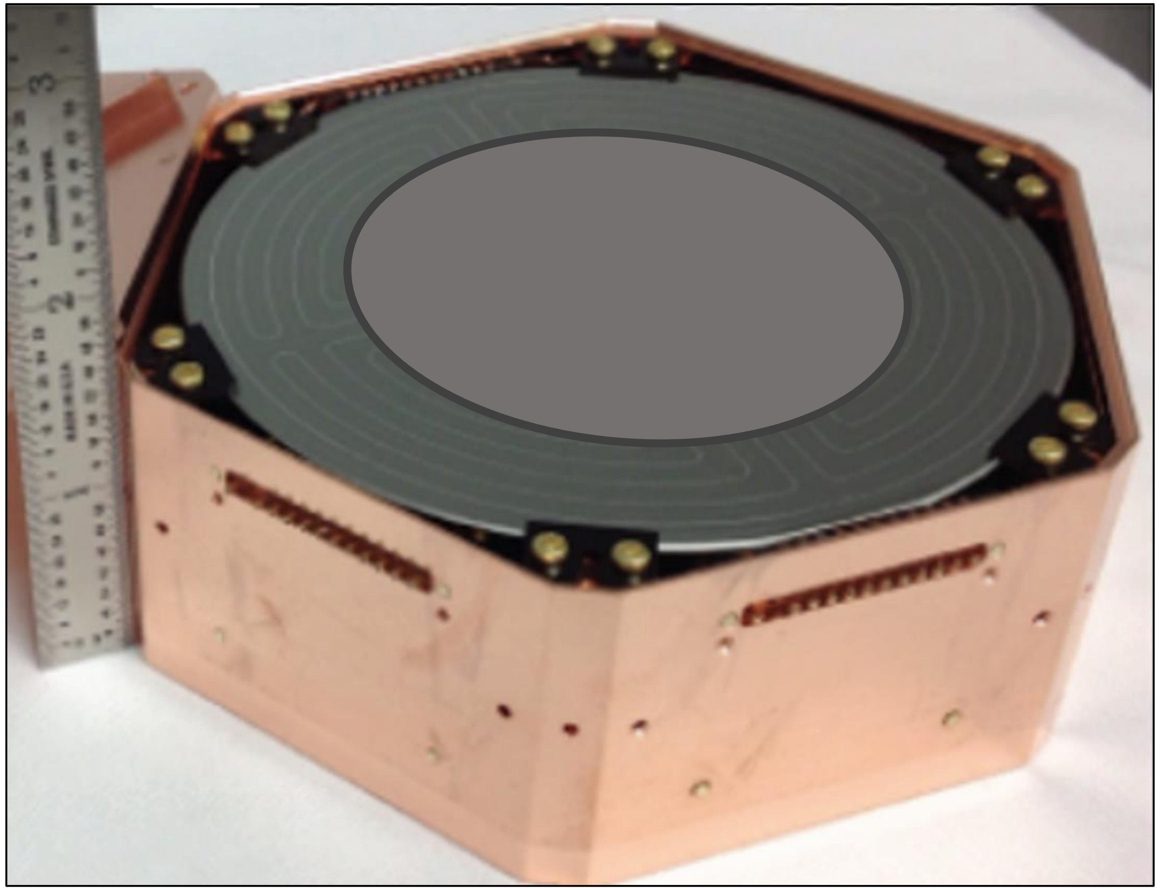
(Very Near) Future Work – Hermetic Veto

- Sandwich stack provides ≥ 25mm active Ge shielding to almost all of the inner detector (top and bottom have less)
- Concept drawing showing future plan with 25mm tall inner detector
- Current inner detector is 4mm tall, currently being installed for cool down next week!





Future Work – Detector Geometries

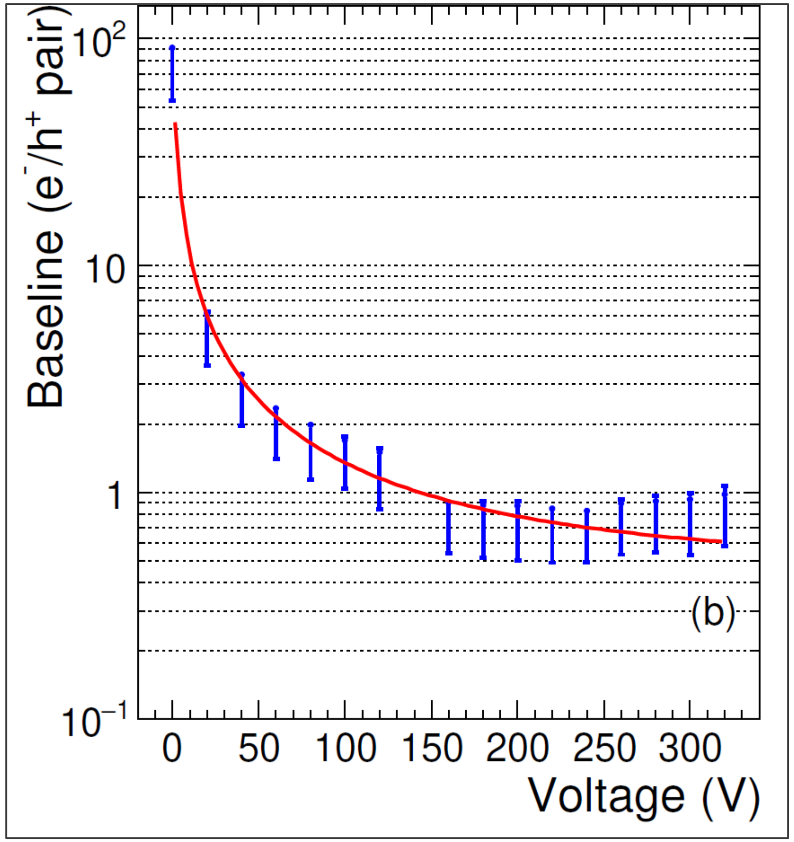


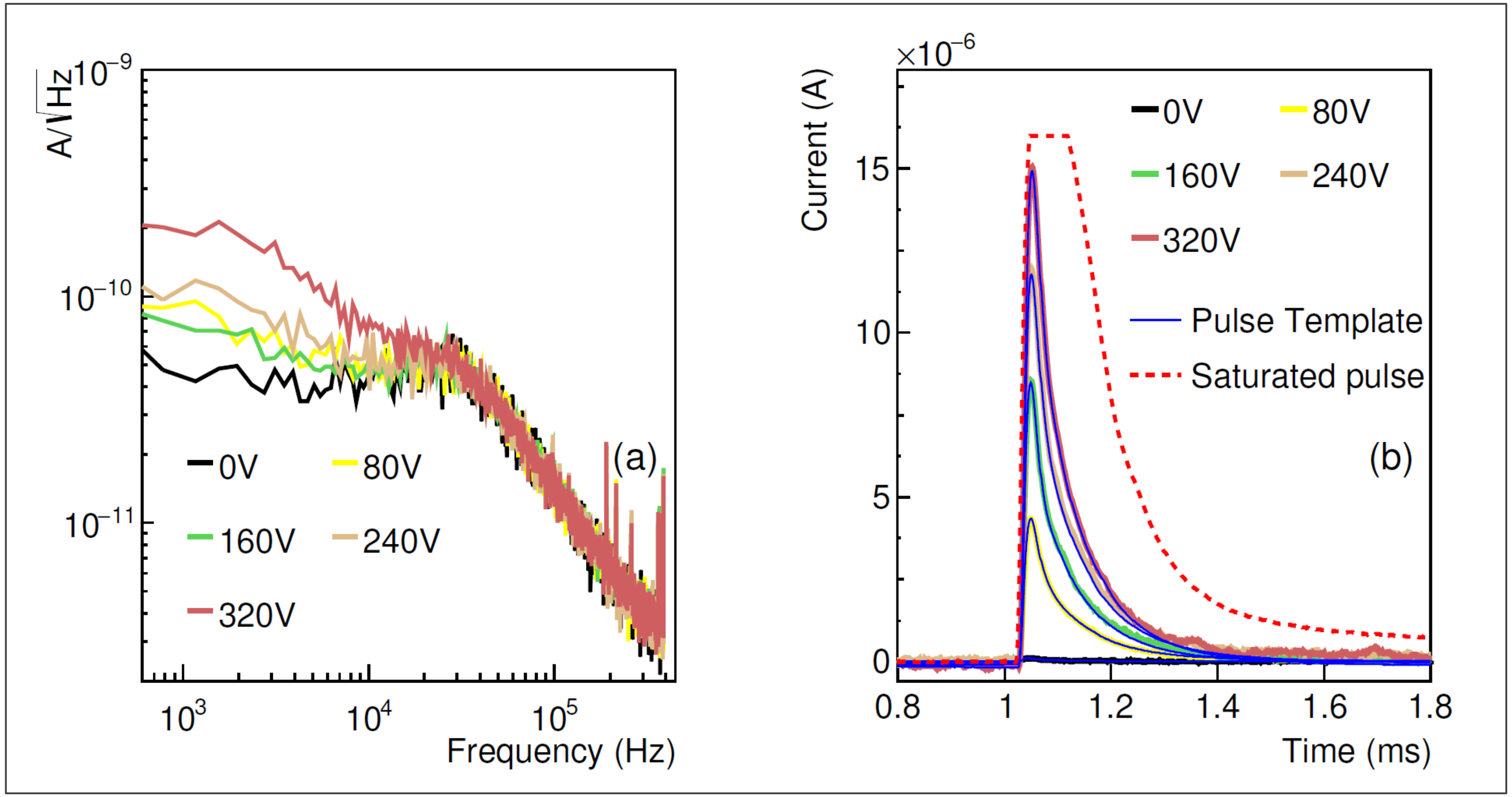
100mm SNOLAB Compatible Modules

150 mm Modules Containing 100 mm Detectors

Future Work – NTL Gain

Future Work – NTL Gain





Iyer, V., et al. "Large-mass single-electron-resolution detector for dark matter and neutrino elastic interaction searches." *arXiv preprint arXiv:2011.02234* (2020).

Future Work – Novel Searches

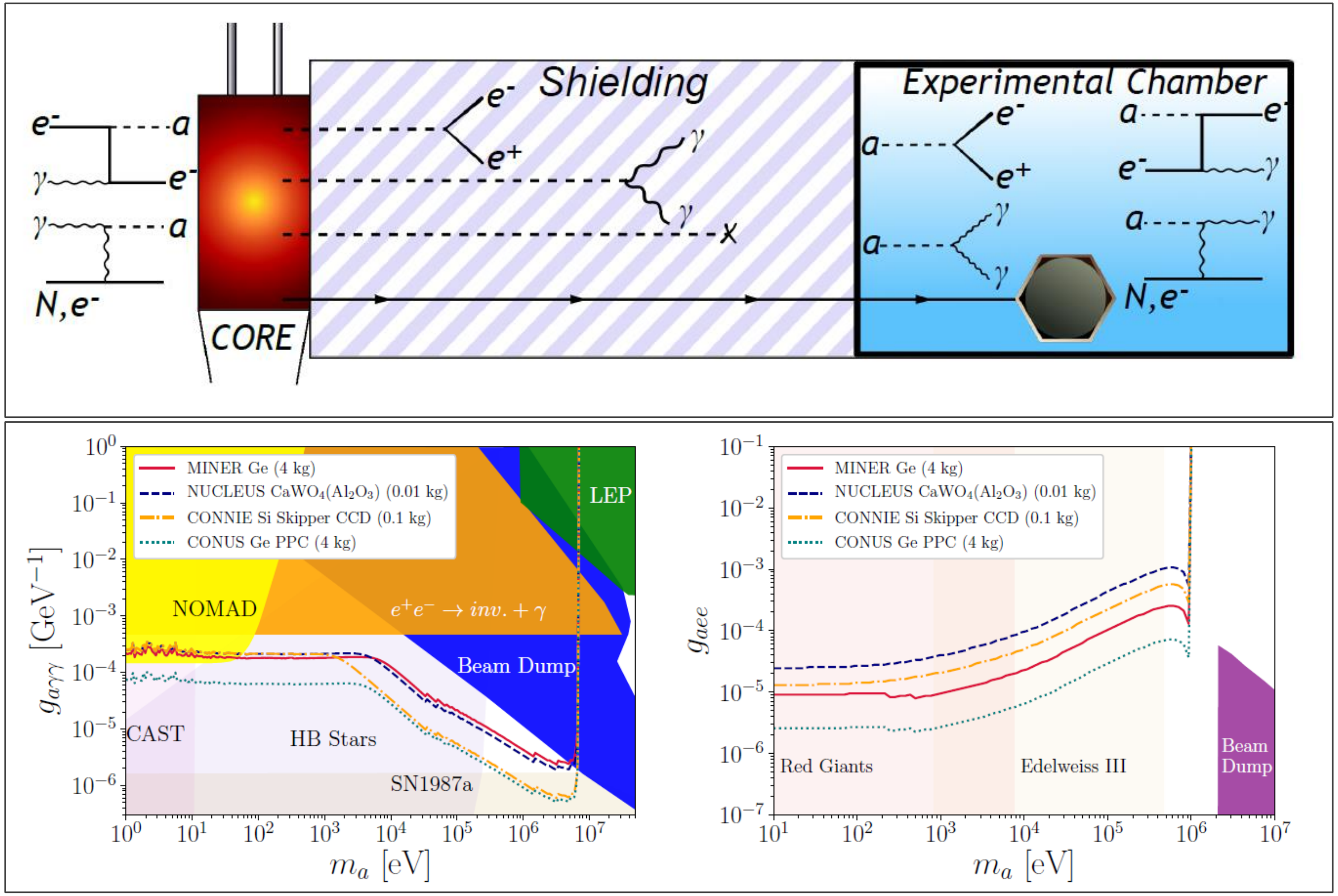
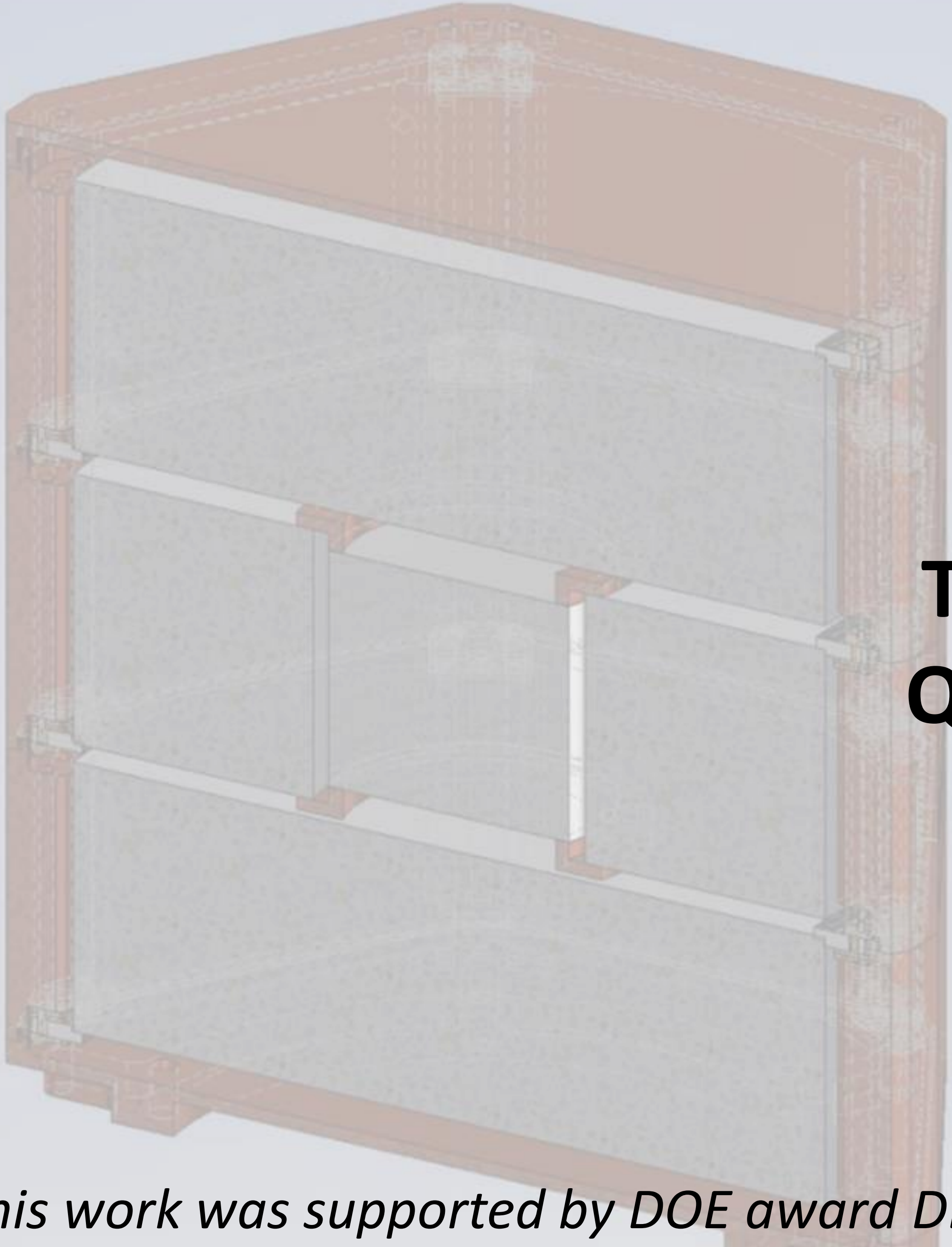
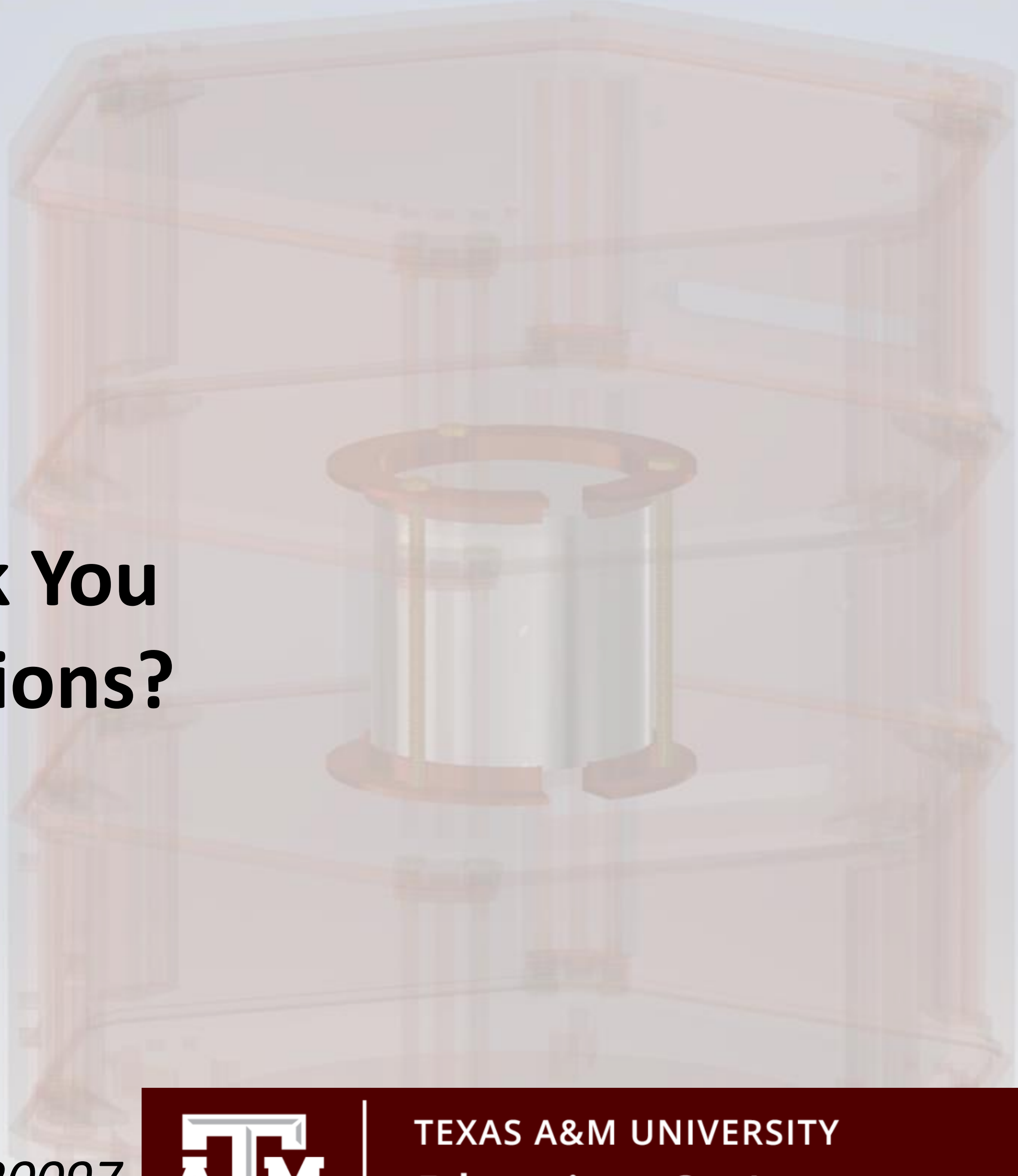


Figure 7: (a) Cartoon of the ALPs and their production (left), scattering, and decay possibilities (right) in MINER. The ALP may decay inside the shielding and evade detection (dashed lines). ALPs that free stream through the shielding (solid line) may be detected via the inverse Primakoff and Compton scattering channels and decay channels, (b) 3-year exposure, derived on the ALP-photon (left) and ALP-electron (right) couplings $g_{a\gamma\gamma}$ and g_{aee} as a function of ALP mass m_a for the MINER, ν-cleus, CONNIE, and CONUS benchmarks [14].

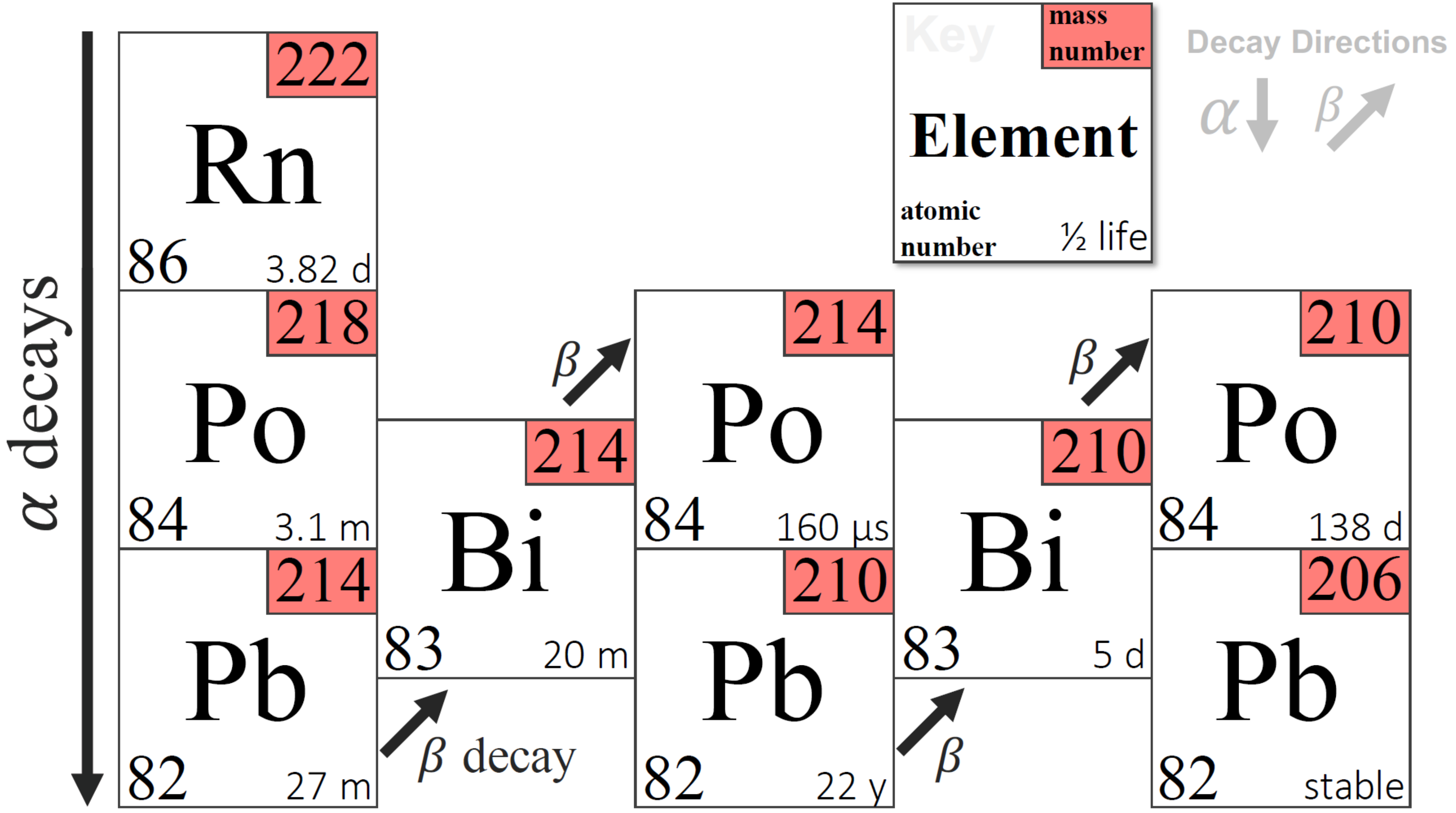




Thank You
Questions?

This work was supported by DOE award DE-SC0020097

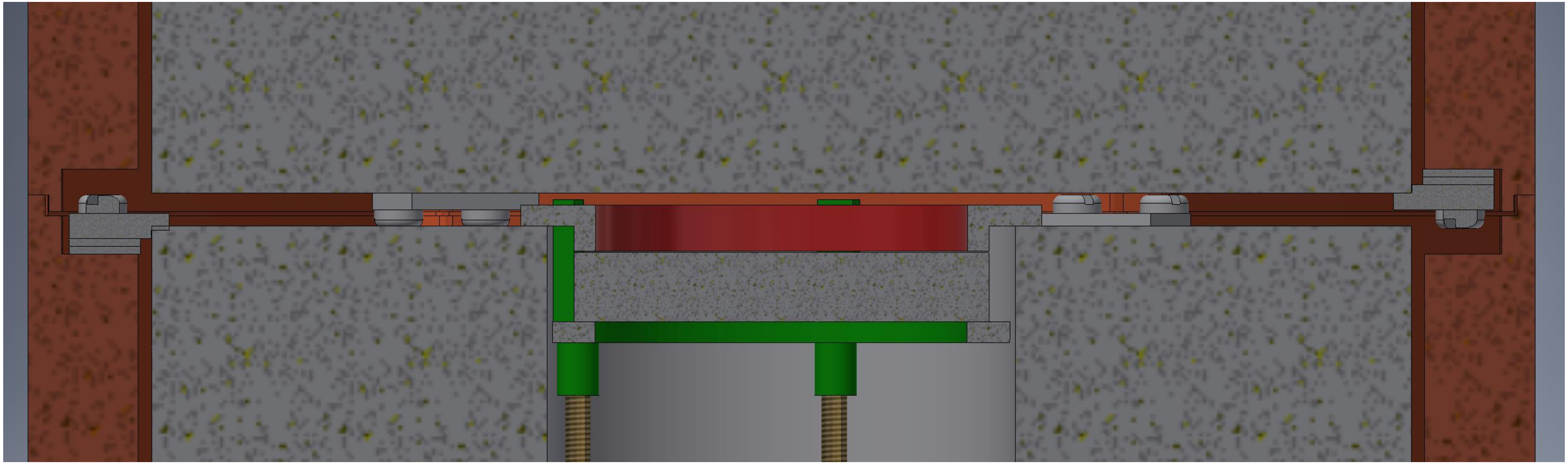
TEXAS A&M UNIVERSITY
Physics & Astronomy

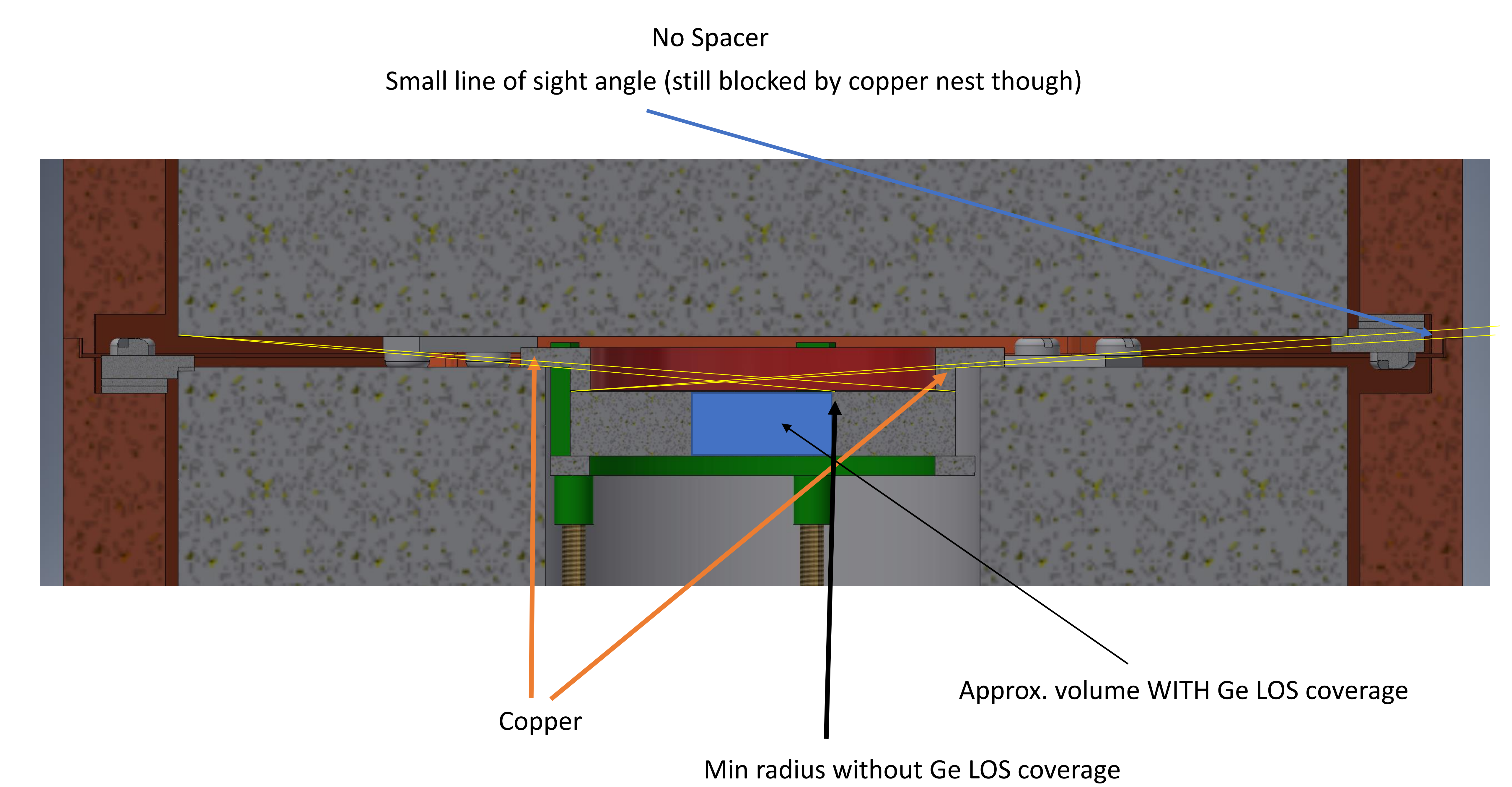


Street, Joseph, et al. "Removal of 210Pb by etch of crystalline detector sidewalls." *Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment* 976 (2020): 164280.

No Spacer

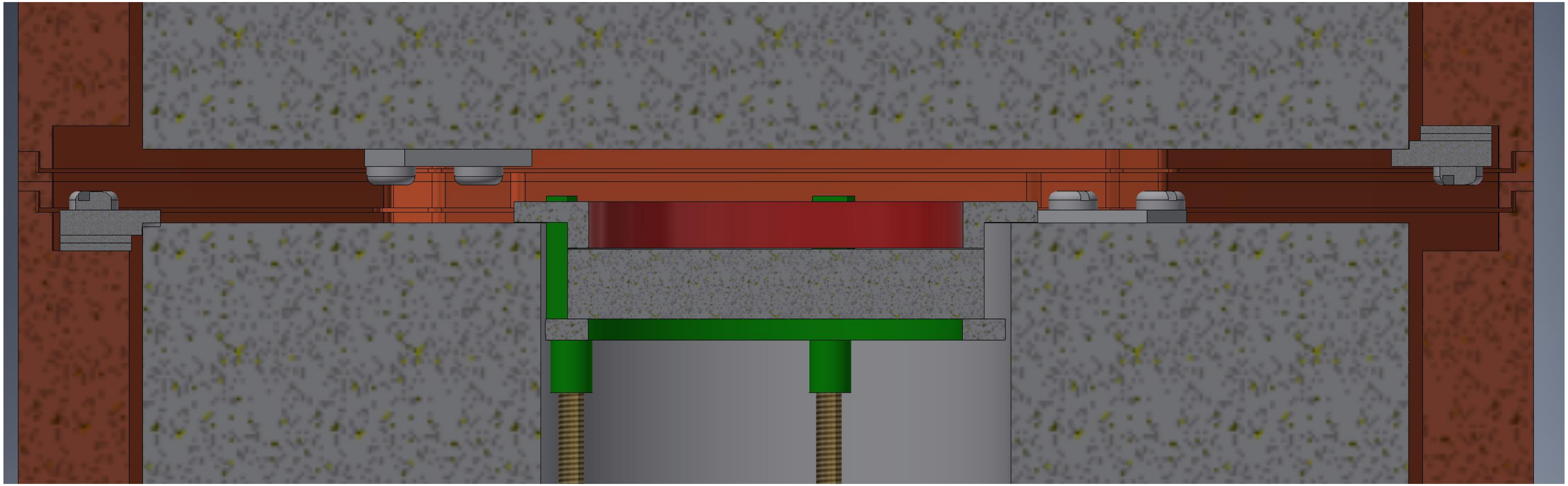
Small line of sight angle (still blocked by copper nest though)




No Spacer
Small line of sight angle (still blocked by copper nest though)
Copper
Approx. volume WITH Ge LOS coverage
Min radius without Ge LOS coverage

0.094” Spacer

Larger line of sight angle (still blocked by copper nest though)



0.094” Spacer

Larger line of sight angle (still blocked by copper nest though)